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Windsor Air Quality Study
L'étude sur la qualité de l'air de Windsor

Windsor Air Quality Committee | Comité sur la qualité de l'air de Windsor

Emission Inventory for the Windsor/Detroit Airshed

REPORTS OF THE WINDSOR AIR QUALITY STUDY

1: Windsor Air Quality Study : Executive Summary
2: Windsor Air Quality Study : Emission Inventory for Windsor/Detroit Airshed
3: Windsor Air Quality Study : Air Monitoring Activities
4: Windsor Air Quality Study : TAGA 6000 Survey Results
5: Windsor Air Quality Study : Personal Exposure Survey Results
6: Windsor Air Quality Study : Soil and Garden Produce Survey Results
7: Windsor Air Quality Study : Mathematical Modelling/Source Apportionment
8: Windsor Air Quality Study : Health Effects Assessment
9: Windsor Air Quality Study : Plain Language Summary

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WINDSOR AIR QUALITY STUDY:

EMISSION INVENTORY

FOR THE

WINDSOR/DETROIT AIRSHED

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WINDSOR AIR QUALITY STUDY:

EMISSION INVENTORY

FOR THE

WINDSOR/DETROIT AIRSHED

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1. INTRODUCTION

1.1 BACKGROUND

Industrialized urban areas may produce substantial air pollutant emissions. Windsor is one of Canada's most industrialized areas with a variety of manufacturing facilities and has a high population density. There are also major emission sources in Detroit of the United States (US). Residents of the Windsor area have been concerned about emissions from the Greater Detroit Resource Recovery Authority's waste incinerator in Detroit, as well as heavy industrial activities on both sides of the Detroit River.

The Ontario Ministry of Environment and Energy (MOEE) maintains an emission inventory for the province to support its role in air pollution control. As part of the Windsor Air Quality Study, the first urban air quality study in Ontario, the Ministry also established an urban emission inventory for the Windsor and Detroit areas which includes pollutants such as sulphur oxides (SO_x), oxides of nitrogen (NO_x), volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins, furans and selected airborne heavy metals.

1.2 THE WINDSOR AIR QUALITY STUDY

One of the objectives of the Windsor Air Quality Study and future urban air quality studies is to measure airborne pollutants and assess their potential effects on human health.

Ultimately, the results of the Windsor Air Quality study will be used to assess the exposure of people to target pollutants and to describe any potential risks associated with that exposure. To achieve the objective, it is necessary to determine as accurately as possible the amounts and types of pollutants emitted to the atmosphere. Pollutant emissions and stack parameters are required inputs for modelling of atmospheric levels of pollutants near ground level. Health risks are then assessed based on modelled levels of pollutants, the exposed populations and the carcinogenic potential of the individual pollutants.

The emission database includes air pollutant sources from the Ontario / Michigan transboundary region in the vicinity of the Detroit River, covering an area of approximately five thousand square miles (Figure 1). The emission inventory for this study consists of two components : (1) a detailed inventory (Windsor emission inventory) for the city of Windsor and (2) a Transboundary emission inventory to assess impacts from adjacent and remote sources. This inventory was compiled from emission sources in the Detroit/Port Huron and Windsor/Sarnia corridor. This is an area of concentrated industrial activity and high population density. The Detroit/Port Huron region comprises seven counties: Lapeer, St. Clair, Oakland, Macomb, Washtenaw, Wayne and Monroe. It is also one of the United States's foremost locations for motor vehicle manufacturing and a wide range of other industrial activities. The Windsor/Sarnia corridor comprises three industrialized Ontario counties : Essex, Kent and Lambton.

The emission calculation procedures and data collection methods used in the emission estimation follow an approach which is consistent with those of the United States Environmental Protection Agency (US EPA) and Environment Canada. For the Windsor inventory, a detailed 1990 emission inventory on a grid size of one by one kilometer square was compiled through an industrial survey of major stationary sources in the Windsor area and through the collection of statistics on various background sources. The emission inventory for the US transboundary region is based on Engineering Science (ES) emission inventory databases, which were previously compiled for the US Transboundary Air Toxics Study (Engineering-Science Inc., 1990). These were subsequently enhanced for MOEE to use in the Windsor Air Quality Study.

The emission inventory of major stationary sources in the Windsor area was compiled through a comprehensive survey in early 1991. The profiles of the selected pollutants were estimated and subsequently verified with the associated industrial and municipal sources. Approximately 70 facilities were categorized as point sources that were considered to be major emitters of the air pollutants listed in Table 1. In-stack monitoring would have been the most accurate means of obtaining the emissions of air pollutants, but in the absence of this type of monitoring data, process emission estimates based of industrial activity and emission factors were used to determine the emission rates. Upon subsequent process emission analyses, the air toxics emission profiles were verified and reconciled with individual companies. In addition, as part of the quality assurance

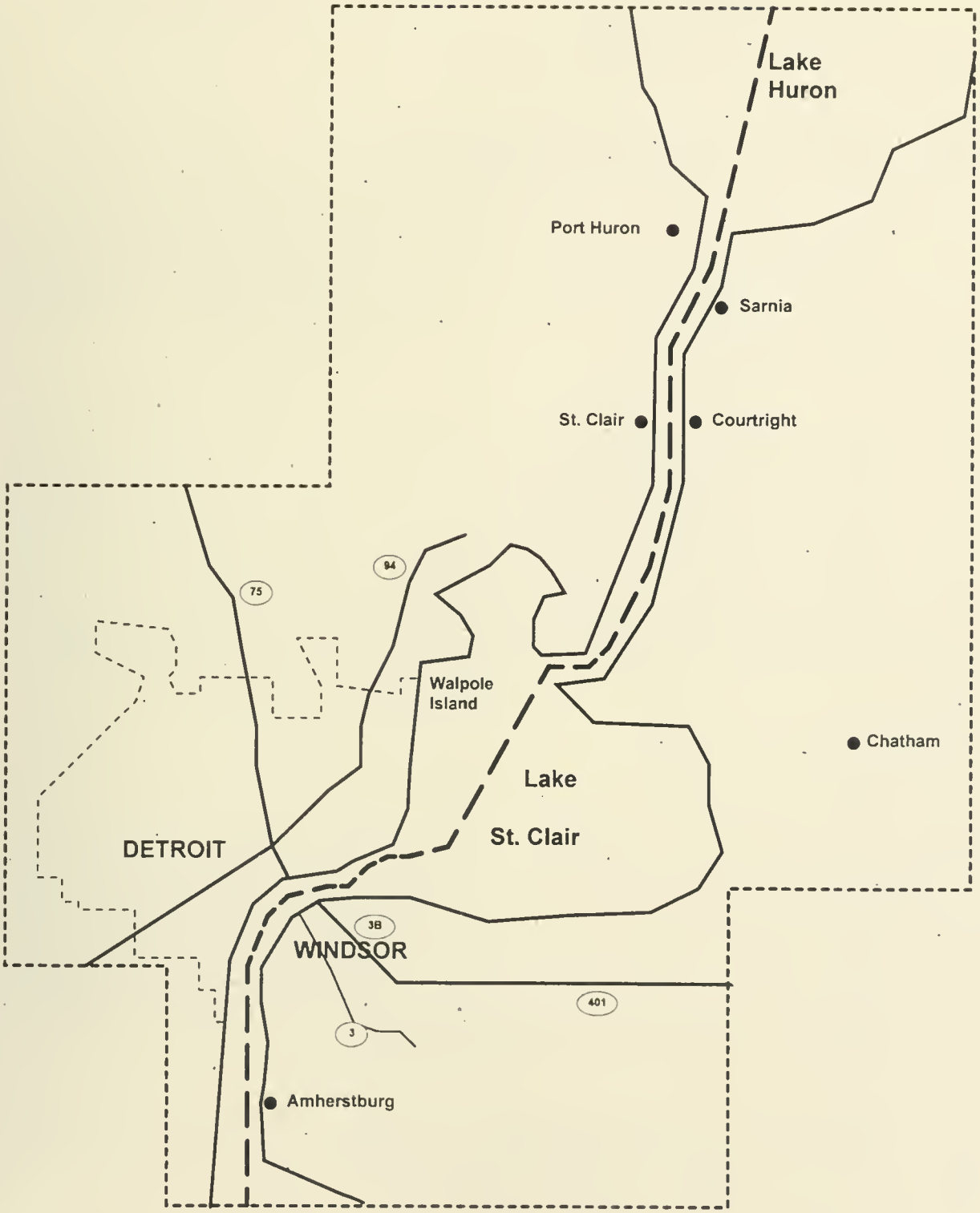


Fig. 1 Transboundary Area of Windsor '91 Study

process, technical meetings were held with several industries to verify further the air pollutant source information supplied.

1.3 THE CITY OF WINDSOR AND SURROUNDINGS

The City of Windsor, incorporated in 1892, is located beside the Detroit River and across the large metropolitan area of Detroit. The 1990 population of the Metropolitan Windsor and the City of Windsor was estimated to be 265,000 and 193,000 respectively.

Windsor has been a manufacturing center for more than a century. The early industries were distilling, corn sugar refining and tobacco processing associated with local farm production. Salt mining began in 1893 and motor vehicles were first manufactured here in 1904. During the 1960s, the Canada-United States Automotive Products Agreement provided the basis for substantial growth in the automotive industry in Windsor. Many of the plants established during the 70s and 80s were a direct result of the need to support this automotive industry.

1.4 EXISTING LAND USE

Residential land use comprises the largest single land use category of the total urbanized Windsor area. The various towns and municipalities that merged during the growth and development of the Windsor area have produced an urban pattern which is irregular and disjointed. The physical layout of the City reflects the previous divided townships and municipalities and their desire to attain full residential, commercial and industrial development.

A large share of automotive pollutants is generated in trips between the home and work-place. The spatial relationship of residential and major industrial employment centers is, therefore, an important factor in assessing automotive exhaust contributions to air pollution loadings. This is particularly important in Windsor where a majority of the employed population drives to work.

The city's oldest industrial districts are located in the central area and include, for example, the Ford engine complex east of Drouillard Road and the General Motor

(GM) Transmission Plant on Walker Road. In the outlying areas, a number of industrial parks and modern automotive plants have been and are being established. These include Morton Industrial Park, Ambassador Industrial Park, Devon Industrial Park, Chrysler Van Plant, Walker Industrial Park, Ford Essex Engine Plant and the GM Trim Plant among others. With reference to Figure 2, it can be seen that each major industrial employment area is located close to a residential neighborhood which provides the opportunity for short travel distances from the home to the workplace.

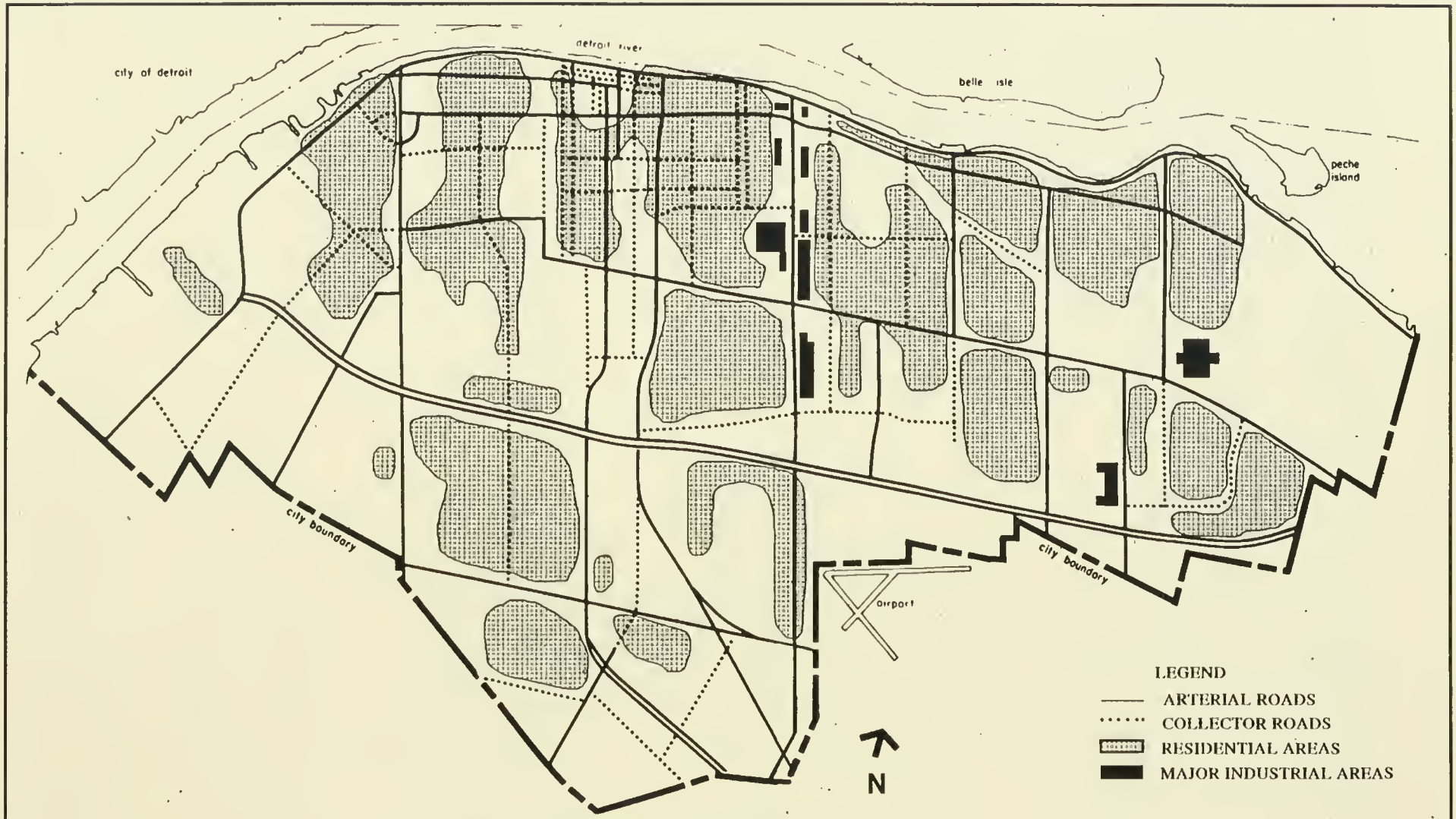


Fig. 2 City of Windsor

2. THE DESIGN OF THE 1990 WINDSOR EMISSION INVENTORY

2.1 GEOGRAPHIC COVERAGE

The emission inventory for the Windsor airshed encompasses an area of 25 km by 15 km, including the City of Windsor and portions of adjacent townships such as LaSalle, Sandwich South and Maidstone. Information was compiled on the basis of one km square study grid cells as shown in Figure 3.

2.2 POLLUTANTS

The pollutants selected for compilation in the Windsor inventory are identified in Table 1. Selection criteria for these pollutants were generally based on the local health risk concerns. The report entitled "Windsor Air Quality Study : Health Effects Assessment" (Szakolcai and Weiler, 1994) provides a description of the selection criteria for the compounds of concern in this study.

2.3 SOURCE CATEGORIES

Emissions of pollutants were quantified for the ambient sources listed in Table 2. Major source categories include the transportation, stationary fuel combustion, open sources and point sources. Methylene chloride (CH_2Cl_2) is listed as a separate pollutant because it is not included in the definition of VOC for both US EPA and Environment Canada.

2.4 SPATIAL DISTRIBUTION OF SOURCES

Area source (non-industrial sources) emission strengths are primarily linked to the population distribution and motor vehicle operation. The distributions of population and Vehicle Kilometer Travelled (VKMT) in Windsor are presented in Figures 4 and 5, respectively. The population core, located between Tecumseh Road and Riverside Drive, represents 25-30,000 people or about 15 percent of the total study area population. The distribution of VKMT follows major highways and roads, and centers on the study cells with highest population density.

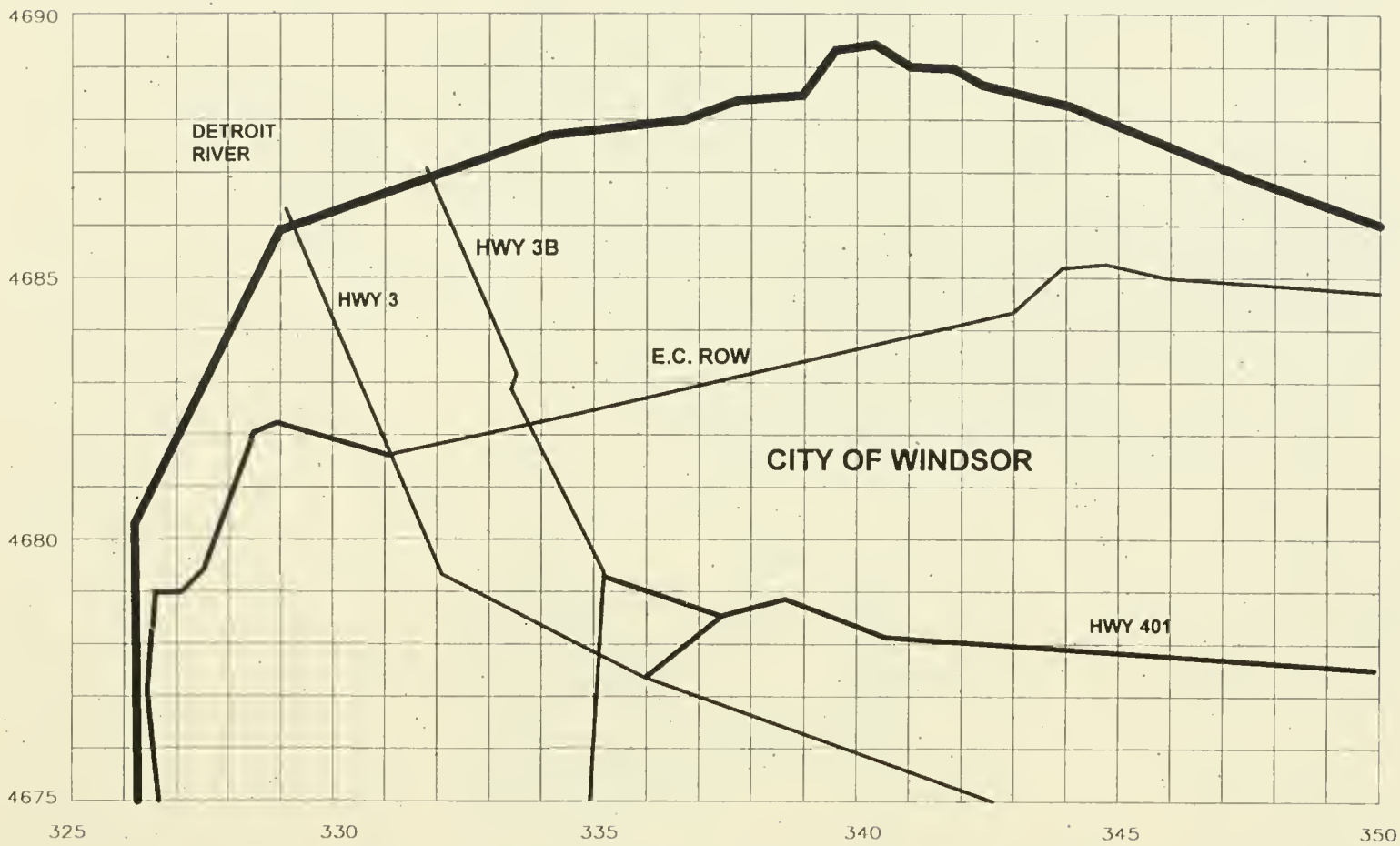


Fig. 3 Geographic Coverage of Windsor Emission Inventory

Table 1

List of Studied Pollutants for the Windsor Emission Inventory

Chlorinated Solvents

Methylene Chloride
Perchloroethylene
Trichloroethylene

Other Organic Compounds

Acrylonitrile
1,2 Dichlorobenzene
1,4 Dichlorobenzene
Vinyl Chloride
Ethylene Dibromide

Common Volatile Organic Compounds

Benzene
1,3-Butadiene
Carbon Tetrachloride*
Chloroform*
Formaldehyde

Metal

Arsenic
Beryllium
Cadmium
Chromium
Lead
Manganese
Mercury
Nickel

Others

Polychlorinated Dibenzofurans (PCDF)

Polychlorinated Dioxins (PCDD)

Polychlorinated Biphenyls (PCBs)

Polycyclic Aromatic Hydrocarbons (PAHs)

*Chloroform and Carbon Tetrachloride are also chlorinated solvents. They are listed under Common Volatile Organic Compounds for their other industrial usage in the Windsor Air Quality Study.

TABLE 2

AMBIENT EMISSION SOURCES INVENTORIED

CATEGORY	POLLUTANTS									
	SO_X	NO_X	CO	PM	VOC	PAH	CH_2CL_2	PCDF	PCDD	PCB
AREA SOURCES										
Transportation										
Aircraft	■	■	■	■	■	■				
Gasoline Motor Vehicles	■	■	■	■	■	■				
Diesel Motor Vehicles	■	■	■	■	■	■				
Off-road Gasoline Vehicles	■	■	■	■	■	■				
Off-road Diesel Vehicles	■	■	■	■	■	■				
Railroads	■	■	■	■	■	■				
Ships	■	■	■	■	■	■				
Stationary Fuel Combustion										
Industrial	■	■	■	■	■	■				
Commercial	■	■	■	■	■	■				
Residential	■	■	■	■	■	■				
Fuelwood	■	■	■	■	■	■		■	■	
Open Sources										
Cigarette Smoking			■	■	■	■				
Landfills			■	■	■	■				■
Road dust				■						
Structural Fires	■	■	■	■	■	■				
Tire Wear				■	■					
Pesticide Use					■					
Consumer Products										
Consumer Solvents and Products					■		■			
Paint Application					■		■			
Industrial/Commercial Area Sources										
Bakeries					■					
Cutback Asphalt*					■					
Dry Cleaning					■					
Gasoline Fuel Marketing					■					
Printing					■					
Body Shops					■					
Miscellaneous Sources										
Home baking					■					
Meat cooking					■	■				
Bioeffluents					■					
Sewage Treatment Plants					■				■	
POINT SOURCES										
Automotive Manufacturing	■	■	■	■	■	■				
Food Processing	■	■	■	■	■	■				
Iron Foundries	■	■	■	■	■	■				
Metal Fabrication	■	■	■	■	■	■				
Pharmaceutical	■	■	■	■	■	■				
Miscellaneous	■	■	■	■	■	■				

■ means that pollutant is inventoried for that specific category.

* cutback asphalt is prepared by blending or "cutting back" asphalt cement with various petroleum distillates and is used in the surfacing of secondary highways.

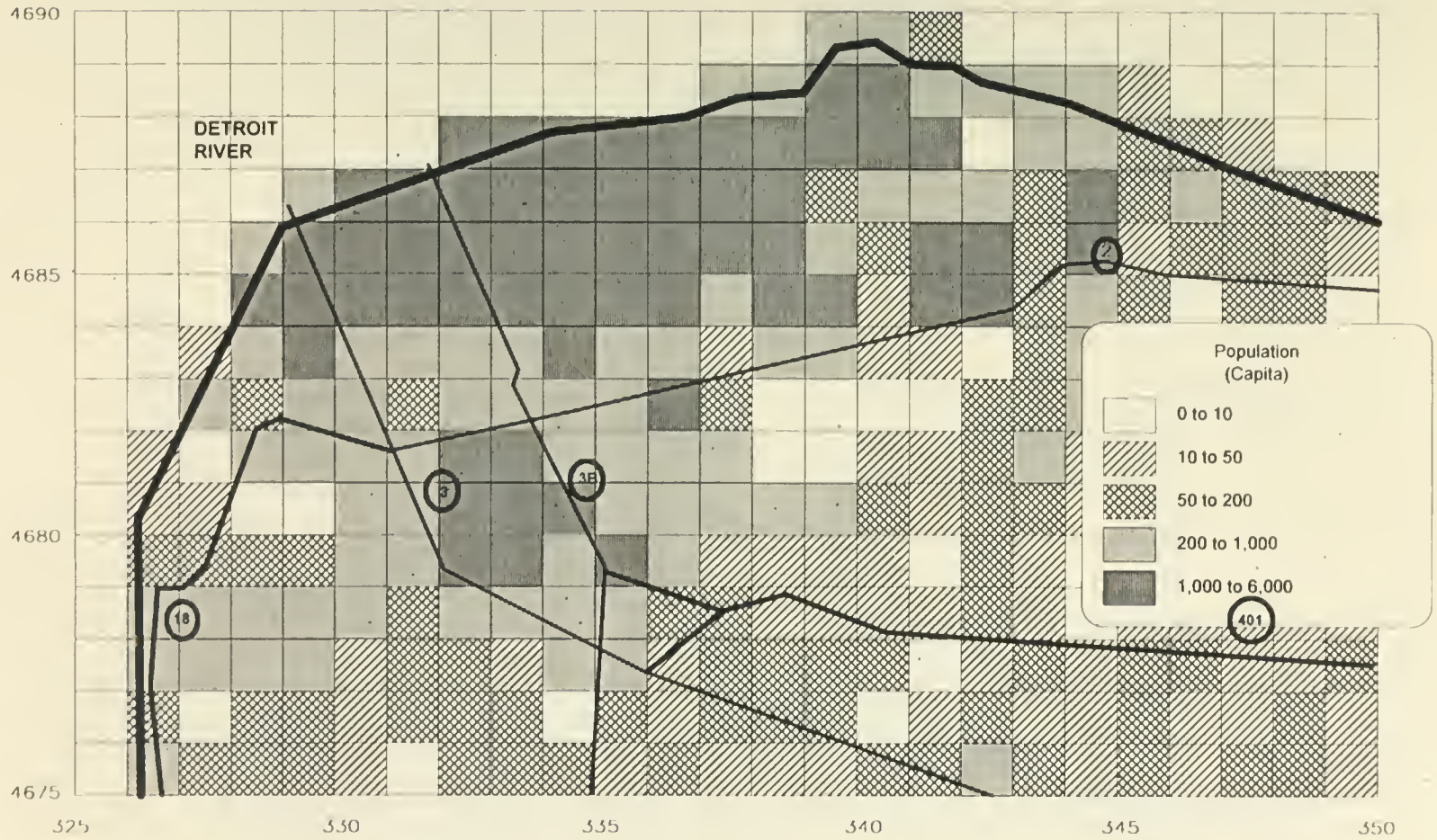


Fig. 4 Population Distribution of Windsor Inventory Area

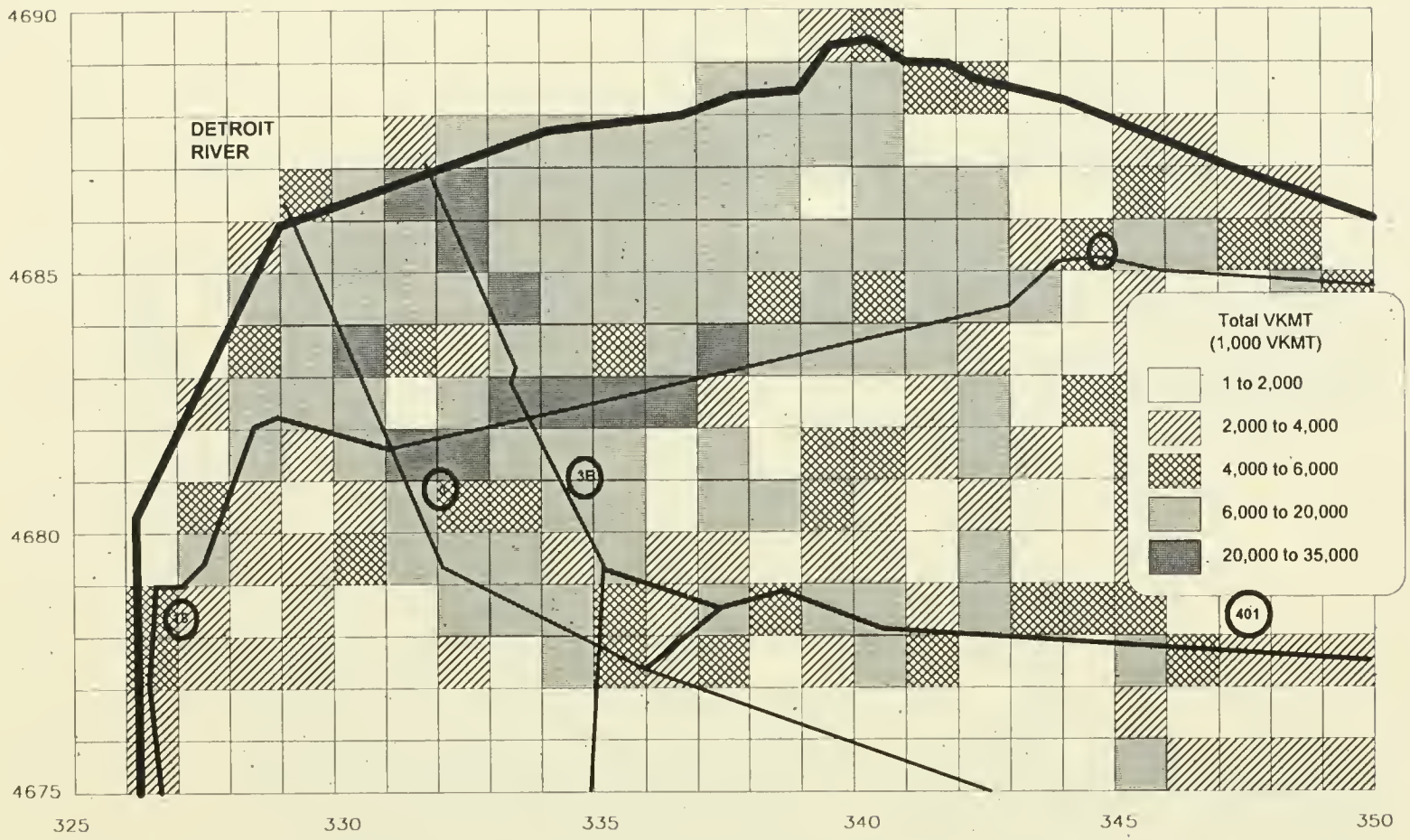


Fig. 5 Total Vehicle Kilometer Travelled For Windsor Inventory Area

Most of the point sources (industrial sources) are distributed throughout the northern half of the study area according to the industrial development in the Windsor area. The industrial sources are classified into automotive manufacturing, iron foundry, food processing, metal fabrication, pharmaceutical manufacturing and miscellaneous sources.

2.5 WINDSOR EMISSION INVENTORY METHODOLOGIES

The compilation of the emission inventory of the Windsor area consisted of estimating air pollutant emissions from significant stationary point sources such as manufacturing plants through a comprehensive survey, and estimating emissions from various area sources such as mobile sources and fuel combustion.

In-stack monitoring would be the most accurate means of obtaining the emissions of air pollutants. In the absence of this type of monitoring data, engineering estimates based on industrial activity data and emission factors are used to determine the emission rates. For this study, computerized databases and calculation techniques were used for the emission estimates. Emission estimates were generally based on the use of air pollutant emission factors, volatile organic compounds (VOC) speciation factors and particulate matters (PM) speciation factors.

The pollutant emissions were estimated by applying speciation factors to the VOC and PM emissions. Most of the speciation factors for specific source types are contained in two volumes of US EPA's Air Emission Species Manual; one for VOC (USEPA/OAQPS, 1988a) and the other for PM (USEPA/OAQPS, 1988b). VOC and PM speciation factors were used to estimate pollutant specific emissions by multiplying the weight fraction for each pollutant with the VOC or PM emissions. PAHs, PCBs, dioxins and furans emissions were generally estimated based on the emission factors contained in the "MOE Toxic Chemical Emission Inventory for Ontario and Eastern North America" (ORTECH 1992) prepared by ORTECH International for MOEE.

Point Sources

For this study, point sources are defined as major industrial installations. Approximately 70 manufacturing plants were categorized in the Windsor Point Source Emission Survey (Figure 6). Air pollution source survey questionnaires were sent to these industries in Windsor and vicinity. In addition to these point sources, several plants in the nearby townships such as Amherstburg, Sandwich, Maidstone were included in the Windsor Inventory. Emissions from smaller plants which did not have large quantities of emissions were excluded in the point source categories; however, they were aggregated into area source categories.

Pollutant emissions can be estimated by one or more of the following methods using the information supplied by the industries:

(1) Mass balance calculation : Emissions can be calculated based on the difference between the pollutant quantities in the feed materials and products or process wastes. Mass balance approach was primarily applied to estimate VOC emissions from solvent usage.

(2) Stack test or continuous emission monitoring results from environmental studies conducted by companies or government agencies, when combined with production rates or operating data, can be used to estimate annual emissions.

(3) Permit system : if available, the related information on emissions from the approval permit system was scanned to obtain a background upper-bound estimate for the process. However, emission estimates from the permit system represent only the full load operation condition, and not the normal operation.

Area Sources

Non-industrial data on area sources were collected from the municipalities, harbor and airport authorities, and from data sources such as Statistics Canada. These data were compiled collectively, and were used to estimate emissions for these collective sources. For example, the aggregated residential natural gas

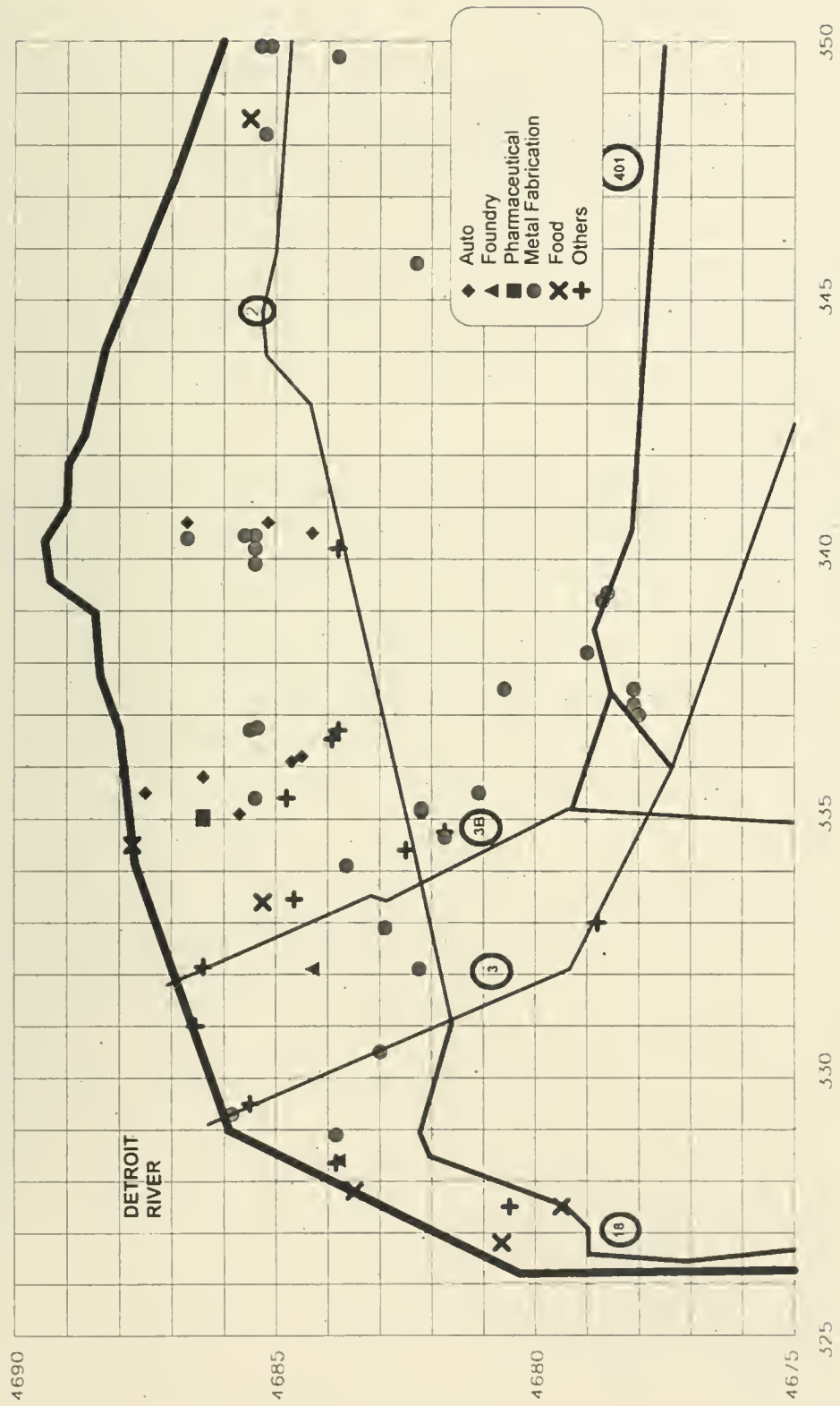


Fig. 6 Spatial Distribution of Point Sources in Windsor

consumption quantities from the one km square grid cells were used to estimate emissions of NO_x , VOC and CO. With the use of emission factors as described in the previous section, it is possible to calculate the emissions from these collective sources. Where possible, area source emission estimates were checked by "top down" method. This was done by apportioning the total emissions estimated from provincial production and/or consumption data to the Windsor area and compared with the detailed inventory compiled locally.

Mobile source air toxic emissions in the Windsor area were estimated by using the Mobile 4C model (Canadian version of EPA's mobile source emission factor model), VKMT and vehicle fleet characteristics to obtain the VOC emissions. The VOC emissions of each grid cell was then used to estimate the emissions for the compounds of concern.

Fugitive emission sources such as evaporative losses from storage tanks, gasoline refills and spillage, and traffic on paved and unpaved roads, etc., are included in the Windsor inventory.

3. WINDSOR EMISSIONS

3.1 WINDSOR EMISSIONS BY SOURCE CATEGORIES

The 1990 annual emissions by source category and pollutant class are provided in Table 3. As is typical in urban areas, motor vehicle emissions predominate or are major contributors in many of the pollutant classes including NO_x , CO, VOC and PAHs. Stationary fuel combustion from industrial, commercial and residential sources is a major contributor of SO_x , PAHs, PCDD and PCDF. Point sources have substantial emissions in each pollutant class and are the major sources of VOC in the Windsor study area. The miscellaneous category includes relatively low levels emissions, including releases of PCDD and PCBs.

The spatial patterns of emissions of SO_x , NO_x and CO are shown in Figure 7. The distribution of these pollutants reflects the effects of point sources, mobile sources and stationary fuel combustion. There is a close correspondence between the base maps of population density and motor vehicle kilometres travelled (Figures 4 and 5). In Figure 8, the spatial patterns of PM and VOC emissions are provided. The particulate sources are concentrated in the north central part of Windsor primarily as a result of airborne road dust. The pattern is similar to that of CO which is also associated to a major degree with the automobile. The VOC emissions pattern reflect the more complex source mixture of transportation and point sources.

A more detailed breakdown of Windsor emissions by each major category is provided in the following sections.

3.1.1 TRANSPORTATION EMISSIONS

The transportation emissions by sector are provided in Table 4. A major SO_x source is from burning of residual oil in ships. NO_x and PM are generated in large amounts by both gasoline and diesel fuelled motor vehicles. Gasoline fuelled motor vehicles are by far the major source of carbon monoxide both within the transportation sector and also within the entire inventory area and this source contributes a large fraction of the VOC emissions. PAHs are generated mostly by motor vehicles in the transportation category. There are no significant emissions

TABLE 3

WINDSOR EMISSIONS BY MAJOR SOURCE CATEGORY

MAJOR GROUP	SO_X Kg/yr x1,000	NO_X Kg/yr x1,000	VOC Kg/yr x1,000	PM Kg/yr x1,000	CO Kg/yr x1,000	CH_2CL_2 Kg/yr x1,000	PAH Kg/yr	PCB g/yr	PCDD g/yr	PCDF g/yr
1 TRANSPORTATION	741	4,515	4,103	594	26,906	--	1,218	--	--	--
2 STATIONARY FUEL COMBUSTION	1,212	2,697	1,113	1,497	5,563	--	3,848	33	36	137
3 OPEN SOURCES	--	12	72	10,039	185	--	3	--	--	--
4 CONSUMER PRODUCT/SOLVENT	--	--	648	--	--	52	--	--	--	--
5 COMM /IND. AREA SOURCE	--	--	576	--	--	--	--	--	--	--
6 MISC AREA SOURCES	5	71	87	3	14	--	41	213	45	--
7 POINT SOURCES	988	2,399	10,646	1,619	2,620	1	--	--	1	1
TOTAL	2,946	9,694	17,245	13,752	35,288	53	5,110	246	82	138

-- denoted either insignificant value or no emission sources detected.

TABLE 4

WINDSOR TRANSPORTATION CATEGORY EMISSIONS

MAJOR GROUP	SO_X Kg/yr x1,000	NO_X Kg/yr x1,000	VOC Kg/yr x1,000	PM Kg/yr x1,000	CO Kg/yr x1,000	CH_2CL_2 Kg/yr x1,000	PAH Kg/yr	PCB g/yr	PCDD g/yr	PCDF g/yr
1 AIRCRAFT	2	14	24	4	116	--	10	--	--	--
2. GASOLINE MOTOR VEHICLES	86	2,504	3,749	391	25,613	--	518	--	--	--
3. DIESEL MOTOR VEHICLES	186	1,487	147	158	656	--	685	--	--	--
4 RAILROADS	16	203	10	11	81	--	2	--	--	--
5. SHIPS	451	308	173	31	440	--	4	--	--	--
TOTAL	741	4,515	4,103	594	26,906	--	1,218	--	--	--

-- denoted either insignificant value or no emission sources detected.

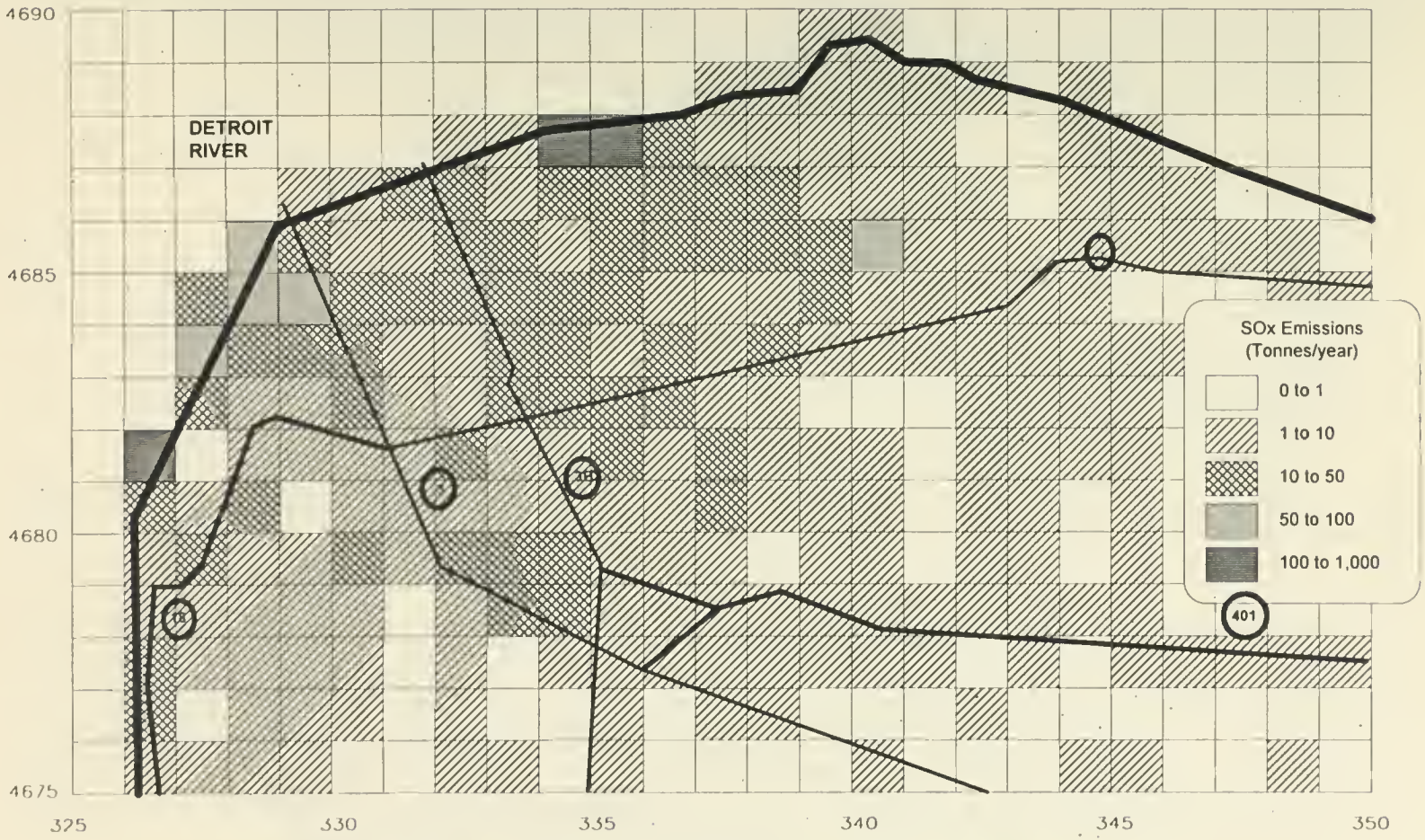


Fig. 7a Spatial Pattern of Annual SOx Emissions

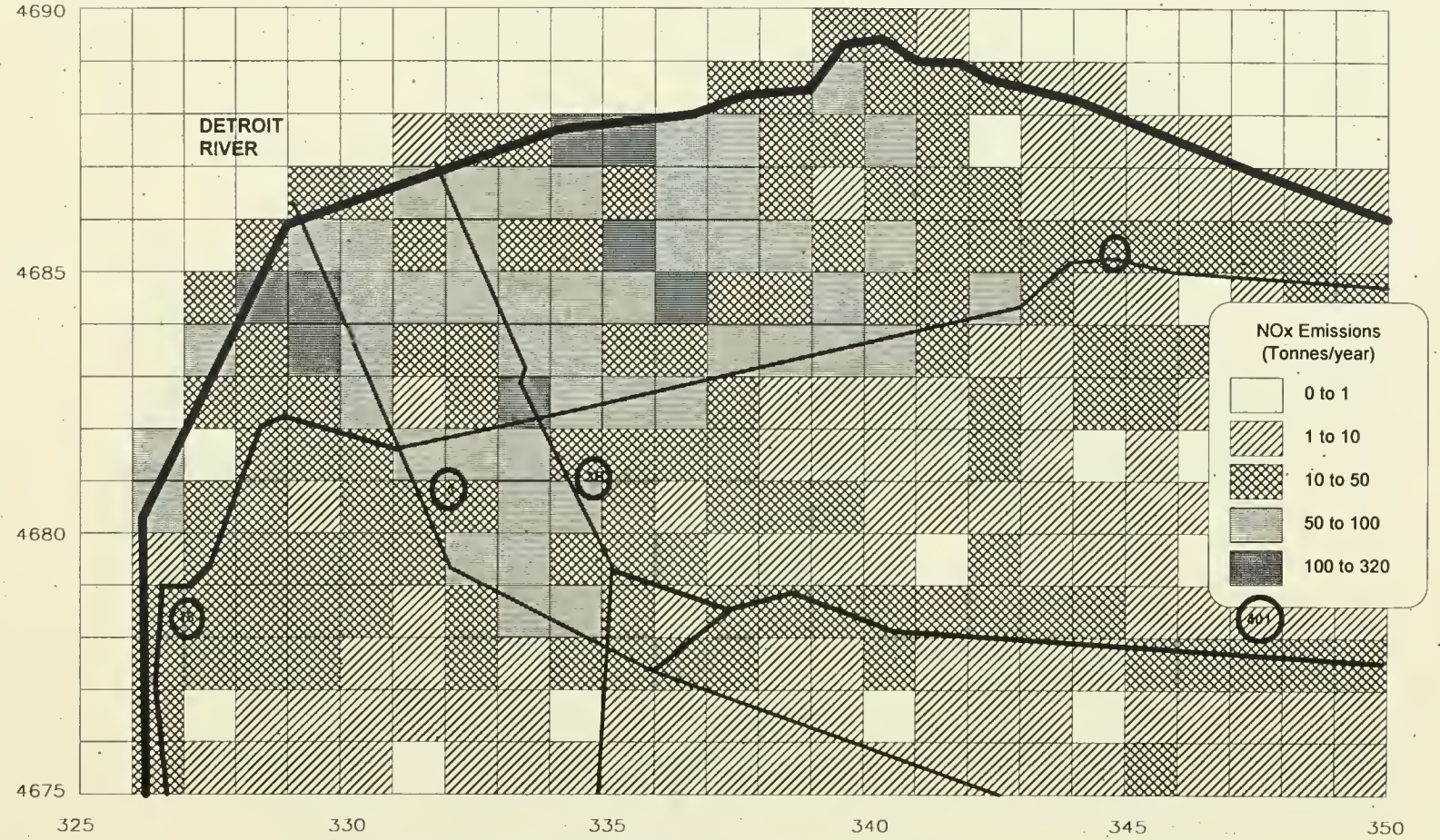


Fig. 7b Spatial Pattern of Annual NOx Emissions

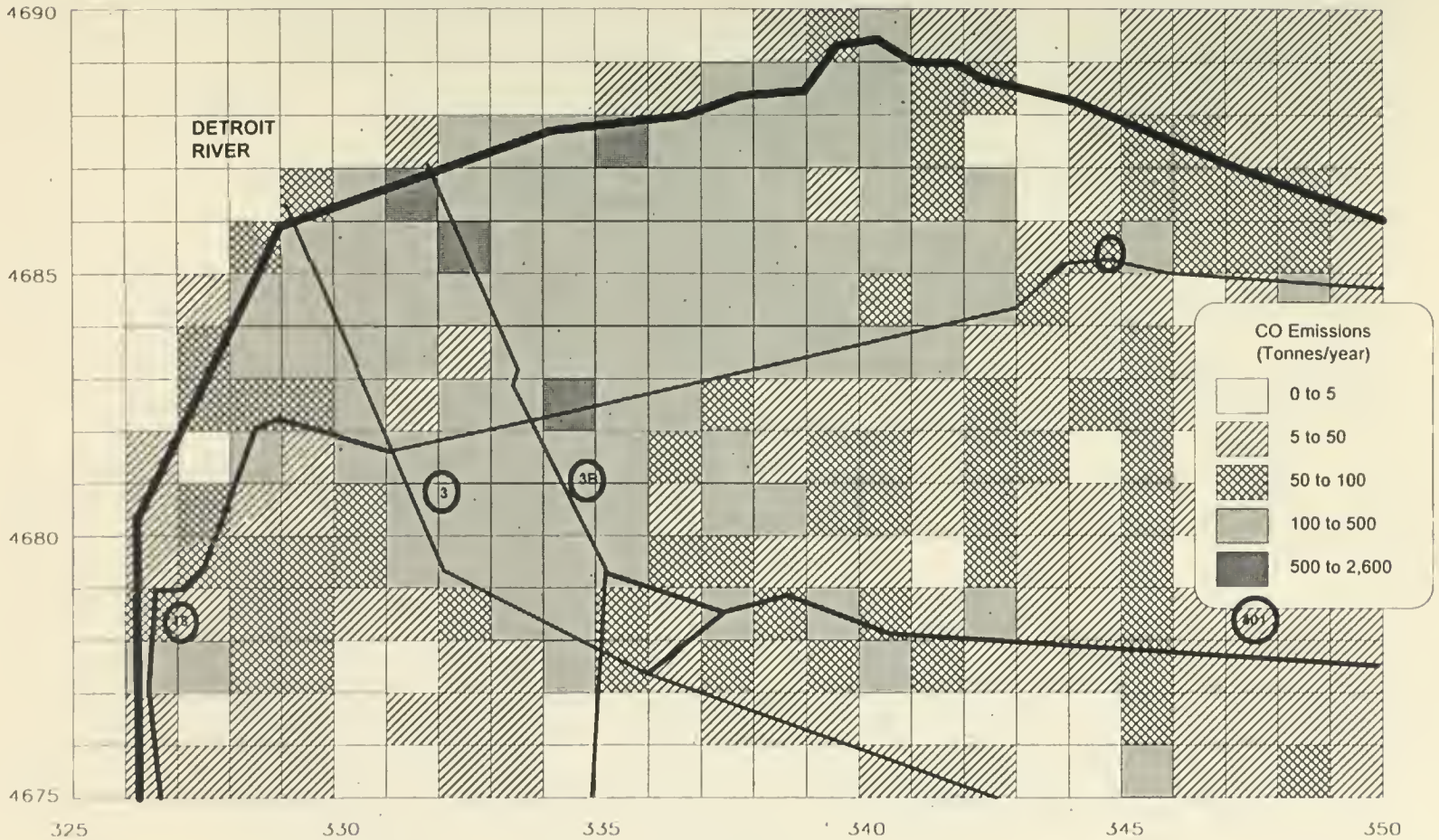


Fig. 7c Spatial Pattern of Annual CO Emissions

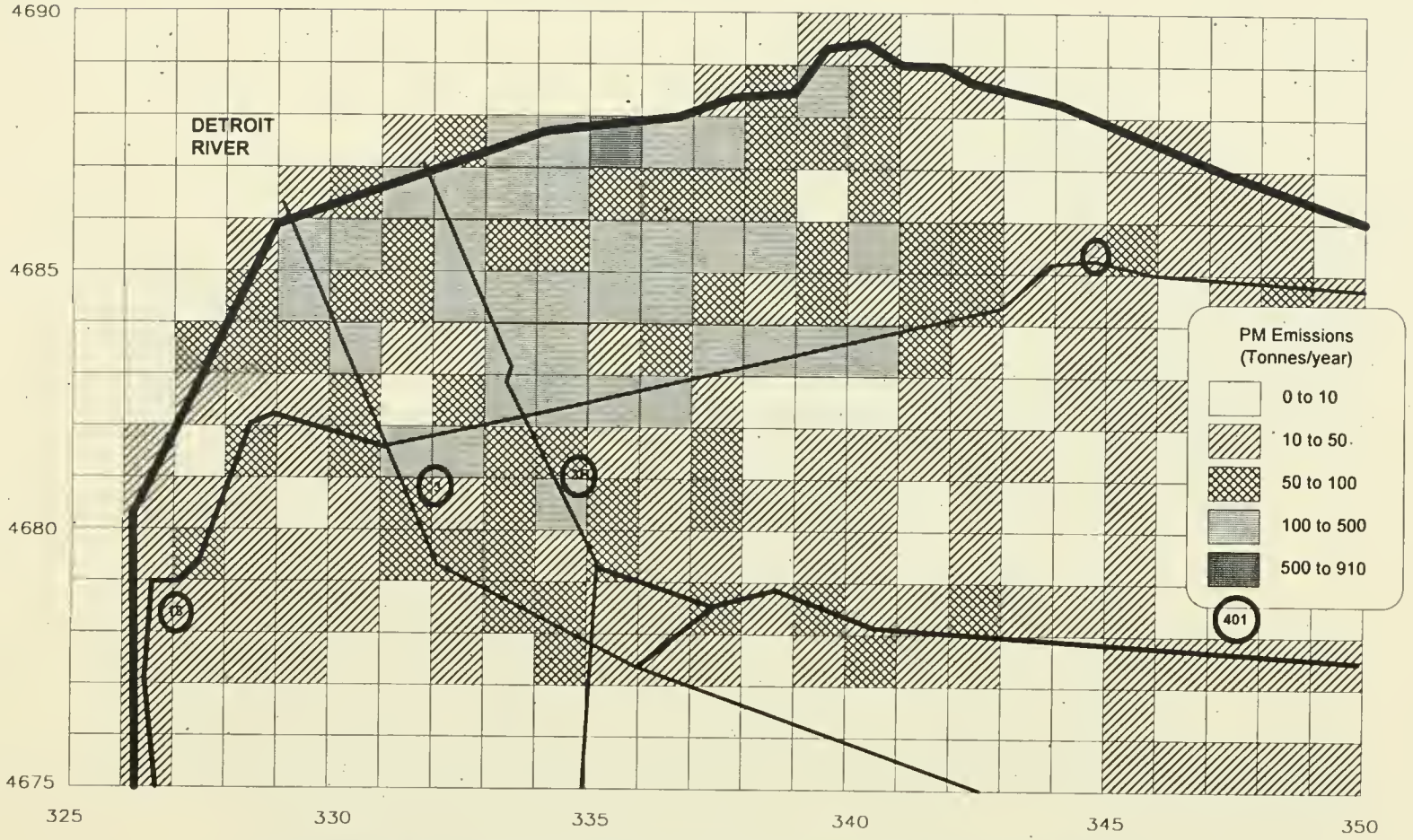


Fig. 8a Spatial Pattern of Annual PM Emissions

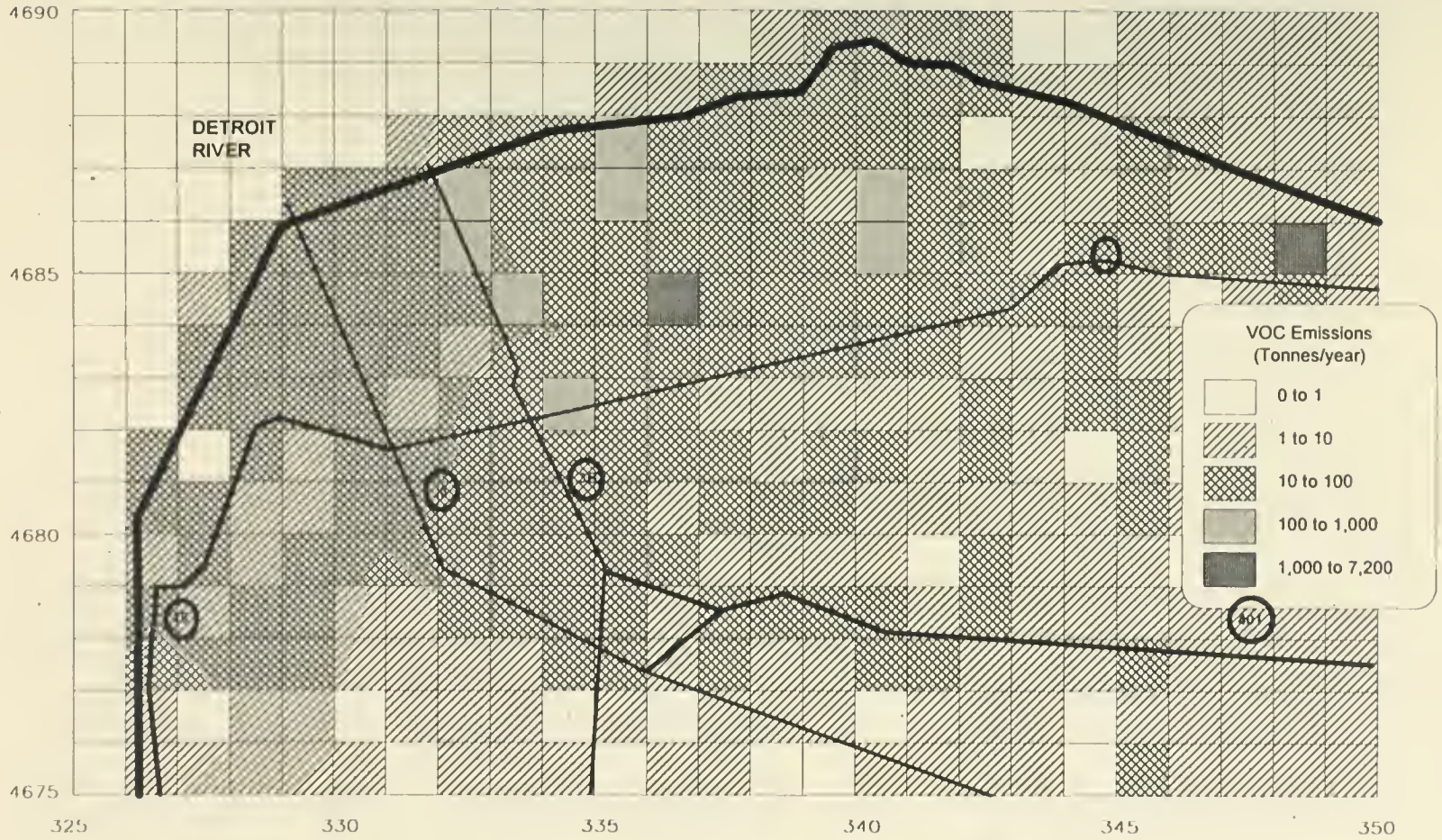


Fig. 8b Spatial Pattern of Annual VOC Emissions

of PCDD, PCDF and PCBs from transportation sources. Emissions from road dust are included under the "Open Source" category in Section 3.1.3.

3.1.2 FUEL COMBUSTION EMISSIONS

For SO_x , total industrial combustion sources contribute 1,058 tonnes, (1 tonnes equal to 1000 kilograms) of which 84% of the emissions result from the combustion of coal (Table 5). All stationary fuel categories, excluding fuelwood, contribute roughly comparable amounts of NO_x . In the remaining pollutant categories, emissions derived from fuelwood use (ORTECH data) in fireplaces and wood stoves outranks the other three source sectors. It contributes 64% of CO, 59% of PM, 55% of VOC, and 96% of PAHs with fuel combustion category. Fuelwood also emits 136 grams of furans and 34 grams of dioxins per year.

3.1.3 OPEN SOURCE EMISSIONS

The predominant open source emission (Table 6) is road dust generated by motor vehicles on paved roads. This source contributes 72% of the total particulate loading in the Windsor emission inventory. The remaining open sources have relatively low emissions of SO_x , NO_x , CO and VOC. The study by National Research Council (NRC 1983) indicated there are emissions of PAHs from the cigarette smoke. It is estimated that cigarette smoking in Windsor contributed about 3 kg of PAHs and this ambient amount is considered minor as compared to that emitted from fuel combustion and transportation sectors.

3.1.4 CONSUMER PRODUCT EMISSIONS

VOC are widely used as solvents and carriers in nail polishes, perfumes, furniture polish, paints and thinners, and other consumer or household products. Emission estimates of VOC from other consumer products such as hair spray, engine degreases, starting fluids and carburettor cleaners are also included in this sector. In total, about 4% of the Windsor VOC releases are from consumer products and paints (Table 7).

TABLE 5

WINDSOR ANNUAL STATIONARY FUEL COMBUSTION EMISSIONS

MAJOR GROUP	SO_X Kg/yr x1,000	NO_X Kg/yr x1,000	VOC Kg/yr x1,000	PM Kg/yr x1,000	CO Kg/yr x1,000	CH_2CL_2 Kg/yr x1,000	PAH Kg/yr	PCB g/yr	PCDD g/yr	PCDF g/yr
1. INDUSTRIAL	1,058	1,543	99	549	301	--	59	33	2	1
2. COMMERCIAL	78	648	40	33	136	--	23	--	--	--
3. RESIDENTIAL	55	479	362	32	1,591	--	80	--	--	--
4 FUEL WOOD	21	26	611	883	3,536	--	3,685	--	34	136
TOTAL	1,212	2,697	1,113	1,497	5,563	--	3,848	33	36	137

-- denoted either insignificant value or no emission sources detected.

TABLE 6

WINDSOR OPEN SOURCE EMISSIONS

MAJOR GROUP	SO_X Kg/yr x1,000	NO_X Kg/yr x1,000	VOC Kg/yr x1,000	PM Kg/yr x1,000	CO Kg/yr x1,000	CH_2CL_2 Kg/yr x1,000	PAH Kg/yr	PCB g/yr	PCDD g/yr	PCDF g/yr
1 CIGARETE SMOKING	--	--	3	7	67	--	3	--	--	--
2. LANDFILLS	--	--	4	--	--	--	--	--	--	--
3 ROAD DUST	--	--	--	9,922	--	--	--	--	--	--
4 STRUCTURE FIRES	--	12	59	59	117	--	--	--	--	--
5 TIRE WEAR	--	--	7	51	--	--	--	--	--	--
TOTAL	--	12	72	10,039	185	--	3	--	--	--

-- denoted either insignificant value or no emission sources detected.

TABLE 7

WINDSOR CONSUMER PRODUCT EMISSIONS

MAJOR GROUP	SO_X Kg/yr x1,000	NO_X Kg/yr x1,000	VOC Kg/yr x1,000	PM Kg/yr x1,000	CO Kg/yr x1,000	CH_2CL_2 Kg/yr x1,000	PAH Kg/yr	PCB g/yr	PCDD g/yr	PCDF g/yr
1. HOUSEHOLD	--	--	161	--	--	45	--	--	--	--
2. AUTOMOTIVE	--	--	99	--	--	6	--	--	--	--
3 COSMETICS	--	--	66	--	--	--	--	--	--	--
4 PAINT APPLICATION	--	--	267	--	--	--	--	--	--	--
5 OTHER CONSUMER SOLVENT AND PRODUCTS	--	--	55	--	--	--	--	--	--	--
TOTAL	--	--	648	--	--	52	--	--	--	--

-- denoted either insignificant value or no emission sources detected.

TABLE 8

WINDSOR INDUSTRIAL/COMMERCIAL AREA SOURCES

MAJOR GROUP	SO_X Kg/yr x1,000	NO_X Kg/yr x1,000	VOC Kg/yr x1,000	PM Kg/yr x1,000	CO Kg/yr x1,000	CH_2CL_2 Kg/yr x1,000	PAH Kg/yr	PCB g/yr	PCDD g/yr	PCDF g/yr
1 BAKERIES	--	--	4	--	--	--	--	--	--	--
2 CUTBACK ASPHALT	--	--	154	--	--	--	--	--	--	--
3. DRY CLEANING	--	--	86	--	--	--	--	--	--	--
4 GASOLINE FUEL MARKETING	--	--	331	--	--	--	--	--	--	--
5 BULK PLANTS/TERMINALS	--	--	--	--	--	--	--	--	--	--
TOTAL	--	--	576	--	--	--	--	--	--	--

-- denoted either insignificant value or no emission sources detected.

3.1.5 INDUSTRIAL/COMMERCIAL AREA SOURCE EMISSIONS

Commercial area sources are responsible for various VOC emissions (Table 8). Combustion emissions associated with these enterprises are accounted for under the stationary fuel combustion category. The emissions from dry cleaning, gasoline fuel marketing (service station filling, automobile refuelling and pump spillage releases) and the application of cutback asphalt in the surfacing of paved roads are of comparable magnitude.

3.1.6 MISCELLANEOUS SOURCE EMISSIONS

Miscellaneous source emissions encompass home baking (use of yeast), meat grilling and frying (both at residences and restaurants) and volatilization of VOC from the surface of sewage treatment ponds (Table 9). Traces of PCBs and PCDD which are initially present in sewage effluent treated by the plants are volatilized during aeration processes at these facilities.

3.1.7 POINT SOURCE EMISSIONS

Automotive manufacturing is the main point source category for all pollutants except NO_x which has a substantial contribution from other miscellaneous point sources (Table 10). Automotive manufacturing contributes 97% of the SO_x , 87% of CO, 70% of PM and 26% of the VOC to the total point source emissions. Relatively high VOC percent contribution from the food processing sector is due to the alcohol evaporative losses in breweries' storage facilities.

3.2 STUDIED POLLUTANT EMISSIONS SUMMARY

The emissions by the studied pollutants for the Windsor Air Quality Study are presented in Table 11. About 463 tonnes of the studied pollutants were emitted annually in Windsor. Of this total, 67% are contributed by area sources and 33% by point sources.

TABLE 9

WINDSOR MISCELLANEOUS SOURCES

MAJOR GROUP	SO_X Kg/yr x1,000	NO_X Kg/yr x1,000	VOC Kg/yr x1,000	PM Kg/yr x1,000	CO Kg/yr x1,000	CH_2CL_2 Kg/yr x1,000	PAH Kg/yr	PCB g/yr	PCDD g/yr	PCDF g/yr
1. HOME BAKING	--	--	24	--	--	--	--	--	--	--
2. MEAT COOKING	--	--	14	--	--	--	27	--	--	--
3. SEWAGE TREATMENT PLANTS	--	--	14	--	--	--	< 1	213	45	--
TOTAL	--	--	52	--	--	--	27	213	45	--

-- denoted either insignificant value or no emission sources detected.

TABLE 10

WINDSOR POINT SOURCES

MAJOR GROUP	SO_X Kg/yr x1,000	NO_X Kg/yr x1,000	VOC Kg/yr x1,000	PM Kg/yr x1,000	CO Kg/yr x1,000	CH_2CL_2 Kg/yr x1,000	PAH Kg/yr	PCB g/yr	PCDD g/yr	PCDF g/yr
1 AUTOMOBILE INDUSTRY	957	698	2,722	1,133	2,290	--	--	--	--	--
2. IRON FOUNDRY	2	4	4	33	5	--	--	--	--	--
3. FABRICATED METAL	--	21	335	12	7	--	--	--	--	--
4 PHARMACEUTICAL	--	1	45	--	--	1	--	--	--	--
5 FOOD	1	183	7,323	116	46	--	--	--	--	--
6. OTHERS	27	1,492	196	325	272	--	--	--	1	1
TOTAL	988	2,399	10,646	1,619	2,620	1	--	--	1	1

--. denoted either insignificant value or no emission sources detected.

TABLE 11

SUMMARY OF EMISSIONS FROM WINDSOR BY STUDIED POLLUTANT

POLLUTANT	TOTAL EMISSIONS Kg/yr	AREA SOURCES Kg/yr	POINT SOURCES Kg/yr
ACRYLONITRILE	1,690	--	1,690
ARSENIC	1,448	1,209	239
BENZENE	139,201	79,470	59,731
BERYLLIUM	9	--	9
1,3-BUTADIENE	34,324	34,317	7
CADMIUM	504	305	199
CARBON TETRACHLORIDE	2,655	64	2,591
CHLOROFORM	2,962	112	2,850
CHROMIUM	1,441	393	1,048
1,2-DICHLOROBENZENE	1,238	1,237	0.72
1,4-DICHLOROBENZENE	12,447	12,447	--
ETHYLENE DIBROMIDE	127	--	127
FORMALDEHYDE	74,529	68,483	6,046
LEAD	11,911	7,740	4,171
MANGANESE	44,287	14,184	30,103
MERCURY	104	8	96
NICKEL	3,176	1,797	1,379
PAHs	5,110	5,110	0.05
PCBs	0.25	0.25	--
PCDD	0.08	0.08	--
PCDF	0.14	0.14	--
PERCHLOROETHYLENE	116,216	74,887	41,329
TRICHLOROETHYLENE	10,025	10,025	--
VINYL CHLORIDE	43	43	--

Note : not all the U.S. target pollutants (section 4.1.1) were found in Windsor because that list was originally derived for the entire Transboundary region, and therefore has pollutants specific to some industries that are not located in the Windsor area.
-- denoted either insignificant value or no emission sources detected.

The following is a brief review of the major features of some of the studied pollutants emitted in the Windsor area.

Benzene

Benzene emissions (Figure 9) from mobile sources represent the largest percentage of benzene emission total in Windsor (52%). The tail-pipe emissions and evaporative losses from the gasoline fuelled passenger vehicles account for about 70% of the mobile sources emissions. The remaining 30% result from other internal combustion mobile sources such as pleasure crafts, aircrafts, gasoline and diesel powered trucks and tractors in the Windsor area. The main industrial sources, including emissions from processes such as melting furnaces, crankshaft casting processes, hot briquette processes, fuel combustion, iron foundry and miscellaneous sectors, contribute 43% of the emission total. The map of benzene emissions (Figure 10) reflects the wide area of benzene emission sources, and the respective concentration in areas of high population and traffic density.

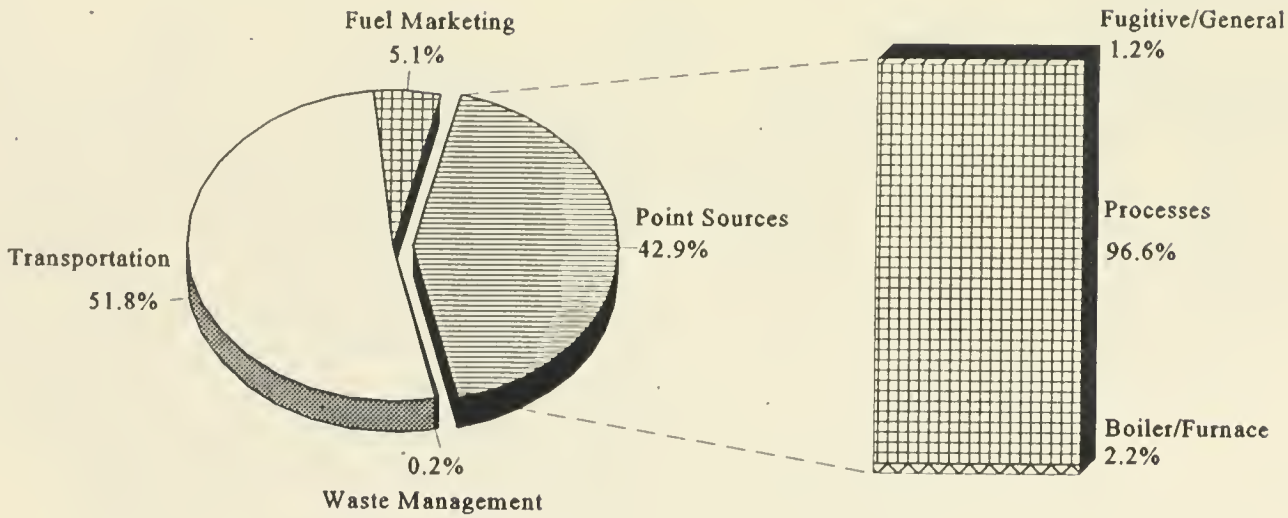
1,3 - Butadiene

1,3 Butadiene is primarily an area source pollutant originating mainly from the exhausts of diesel and gasoline on-road vehicles, and off-road engines such as lawnmowers. In Windsor, the on-road and off-road vehicles account for over 90% of the emission total (Figure 11). The main industrial sources include engine exhausts from the vehicles testing at automobile assembly lines.

Carbon Tetrachloride

In Windsor, carbon tetrachloride is used in the manufacturing of refrigerant gases. Although carbon tetrachloride can be used as an industrial solvent, none of the plants surveyed, reported its usage in the chemical industry. Trace amounts are also emitted from the industrial effluent and landfills (Figure 12).

Fig. 9 Sources of Emissions
Benzene



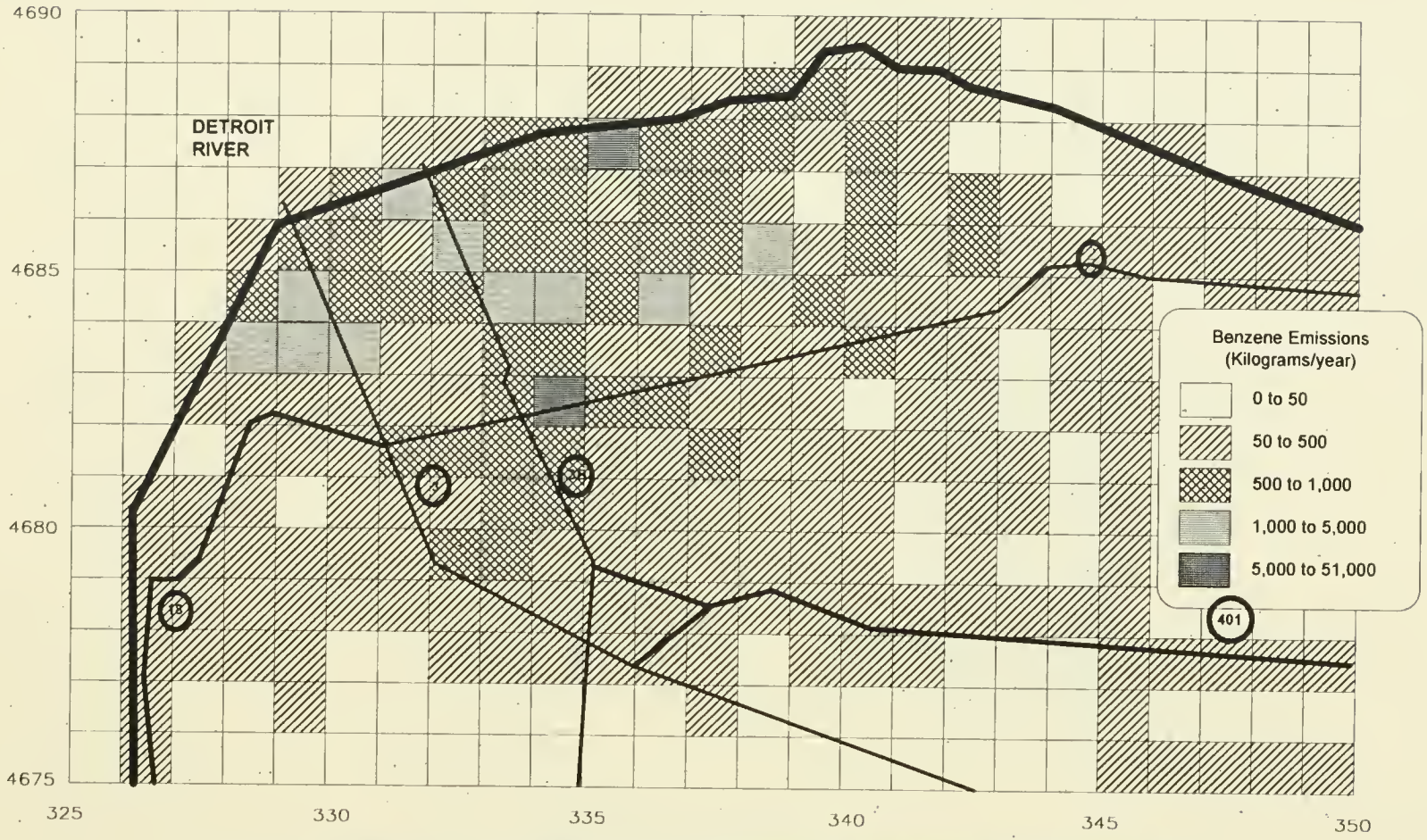


Fig. 10 Spatial Pattern of Annual Benzene Emissions

Fig. 11 Sources of Emissions
1,3-Butadiene

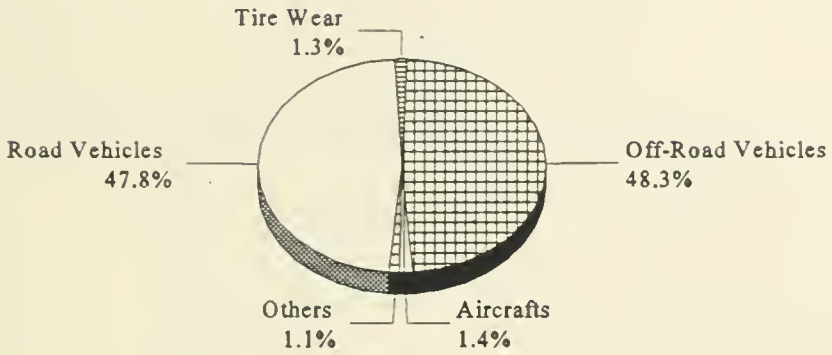


Fig. 12 Sources of Emissions
Carbon Tetrachloride

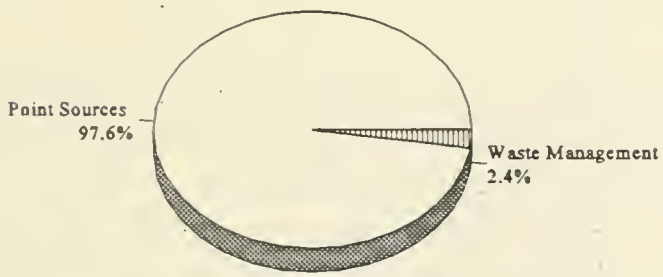
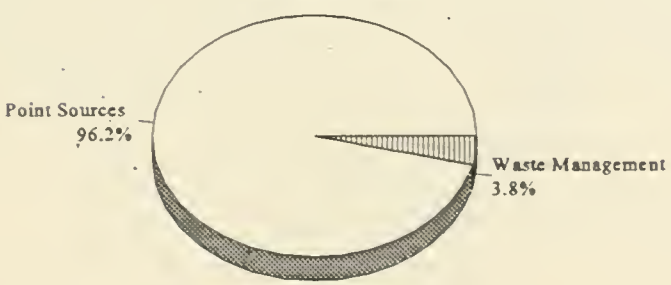


Fig. 13 Sources of Emissions
Chloroform



Chloroform

Chloroform was widely used for many years as an anesthetic and as industrial solvent. However, chloroform usage as an anaesthetic and solvent at the present time has been greatly reduced due to its health risk concerns. None of the point sources surveyed in Windsor reported any usage of chloroform as an anaesthetic or solvent. The only reported usage of chloroform in Windsor is as a reactant in the production of refrigerant gases. Chloroform emissions were estimated to be about 3 tonnes (Figure 13).

The mathematical modelling results (Bloxam and Sahota, 1994) computed from this emission data are much smaller than the observed concentrations (i.e. about 10 to 40 times smaller). Unreported point sources and missing area sources may be some of the probable causes of discrepancies.

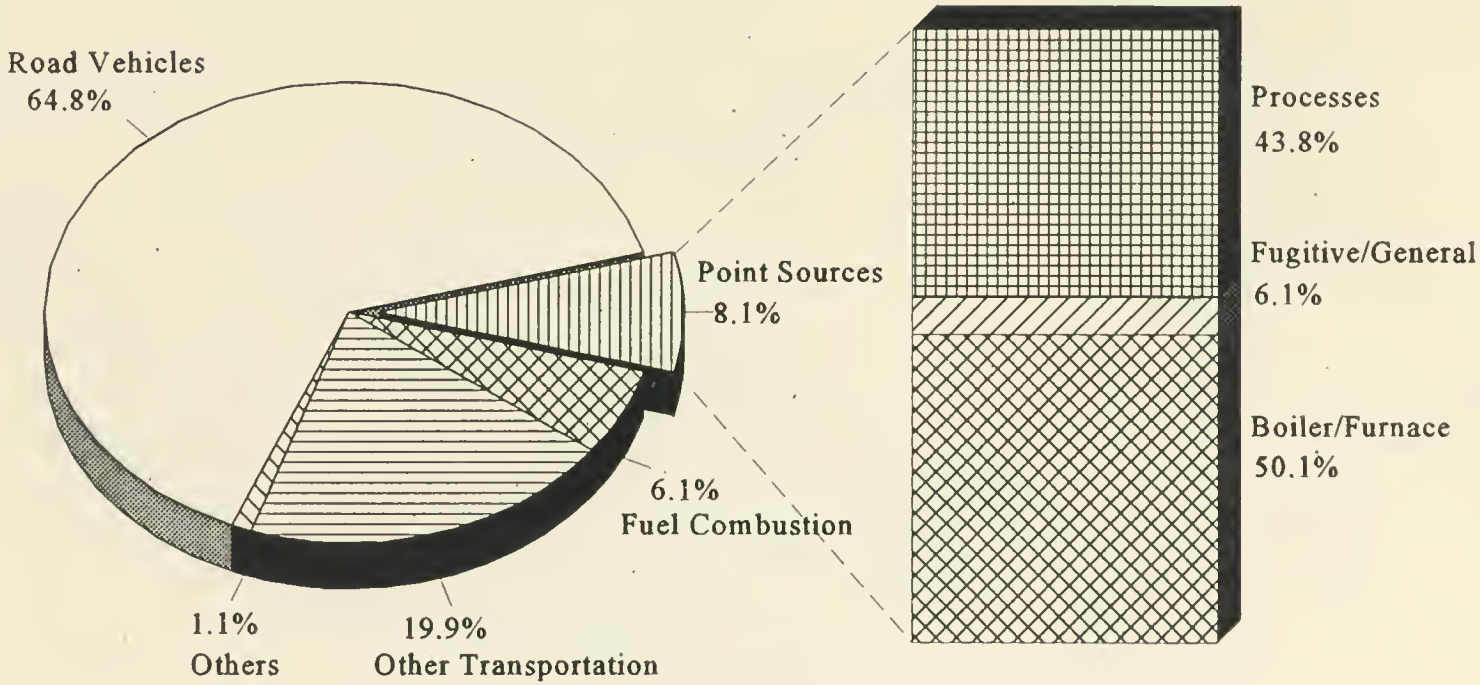
Formaldehyde

Formaldehyde (Figure 14) primarily originates from transportation (85%) and oil combustion exhausts (6%). Industrial sources account for 8% of the emissions. Most of the industrial formaldehyde emissions originate from iron foundry/automotive casting processes and from fuel combustion. The spatial distribution of formaldehyde emissions (Figure 15) is similar to that of benzene although the high emission squares can also be associated with point sources as well as area sources. Photochemical reactions can produce formaldehyde which can subsequently be transported into the study area. This long range transported ambient pollutant has not been compiled in this inventory. However, such background concentration was estimated and used in the Mathematical Modelling and Source Apportionment Study (Bloxam and Sahota, 1994).

Perchloroethylene

About 98% of perchloroethylene is emitted by dry cleaning establishments. Perchloroethylene is released from other industrial processes. Minor amounts of the pollutant are released from engine degreasing, landfills and sewage treatment

Fig. 14 Sources of Emissions
Formaldehyde



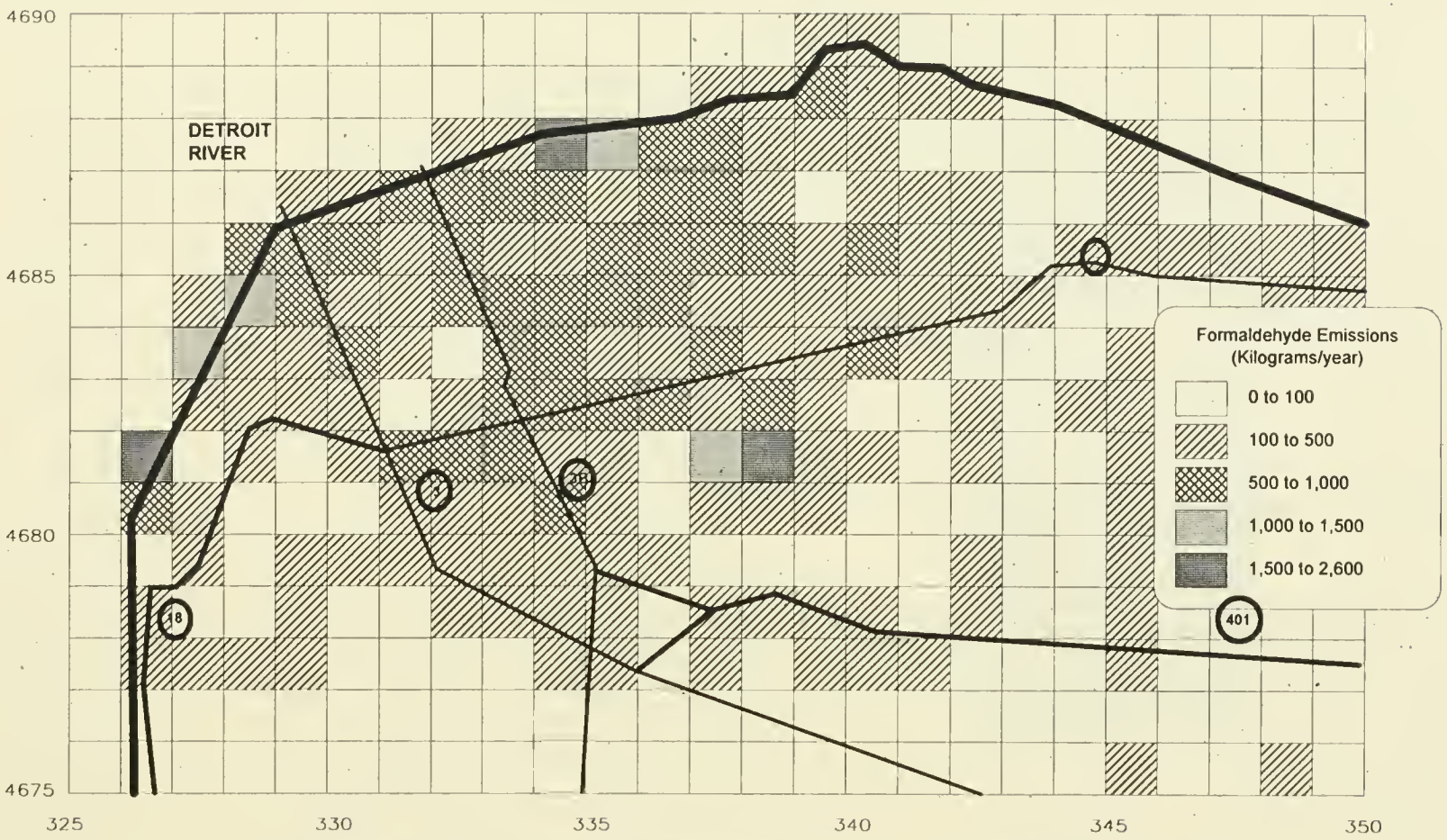


Fig. 15 Spatial Pattern of Annual Formaldehyde Emissions

plants. The map of emissions (Figure 16) indicates that the spatial distribution of these sources is corresponding to the high population areas.

Trichloroethylene

Trichloroethylene is present in the industrial effluent to the two Windsor sewage treatment plants - Windsor West and Little River, and is released from the aeration processes at these facilities. It is estimated that the contribution from the above sector accounted for over 90% of the total trichloroethylene emissions in Windsor.

Chromium

In general, chromium is emitted from direct sources such as chromium plating, chromic acid production and ferrochromium production. Although Windsor does not have such key sources, chromium emissions are estimated to be about 1440 kg, mainly resulting from secondary sources such as combustion. Small amounts of chromium are emitted from iron foundry and automotive casting processes, hot briquetting operations, application of paints and fuel combustion (73%) (Figure 17). The main area sources are stationary fuel combustion (23%) and motor vehicle exhausts (4%). The contribution of industrial sources and motor vehicle exhausts is illustrated by the spatial pattern of emissions (Figure 18).

Nickel is emitted from iron foundry and automotive casting processes, and in smaller amounts from fuel combustion (Figure 19). Area sources primarily include transportation exhausts and stationary fuel combustion.

Cadmium

The point sources contribute about 40% of total cadmium (Figure 20). Industrial sources include iron foundry/automotive casting processes and application of paints. Road dust contributes almost 99% of the total area source emissions. According to a study by Environmental Applications Group (EAG 1988), the

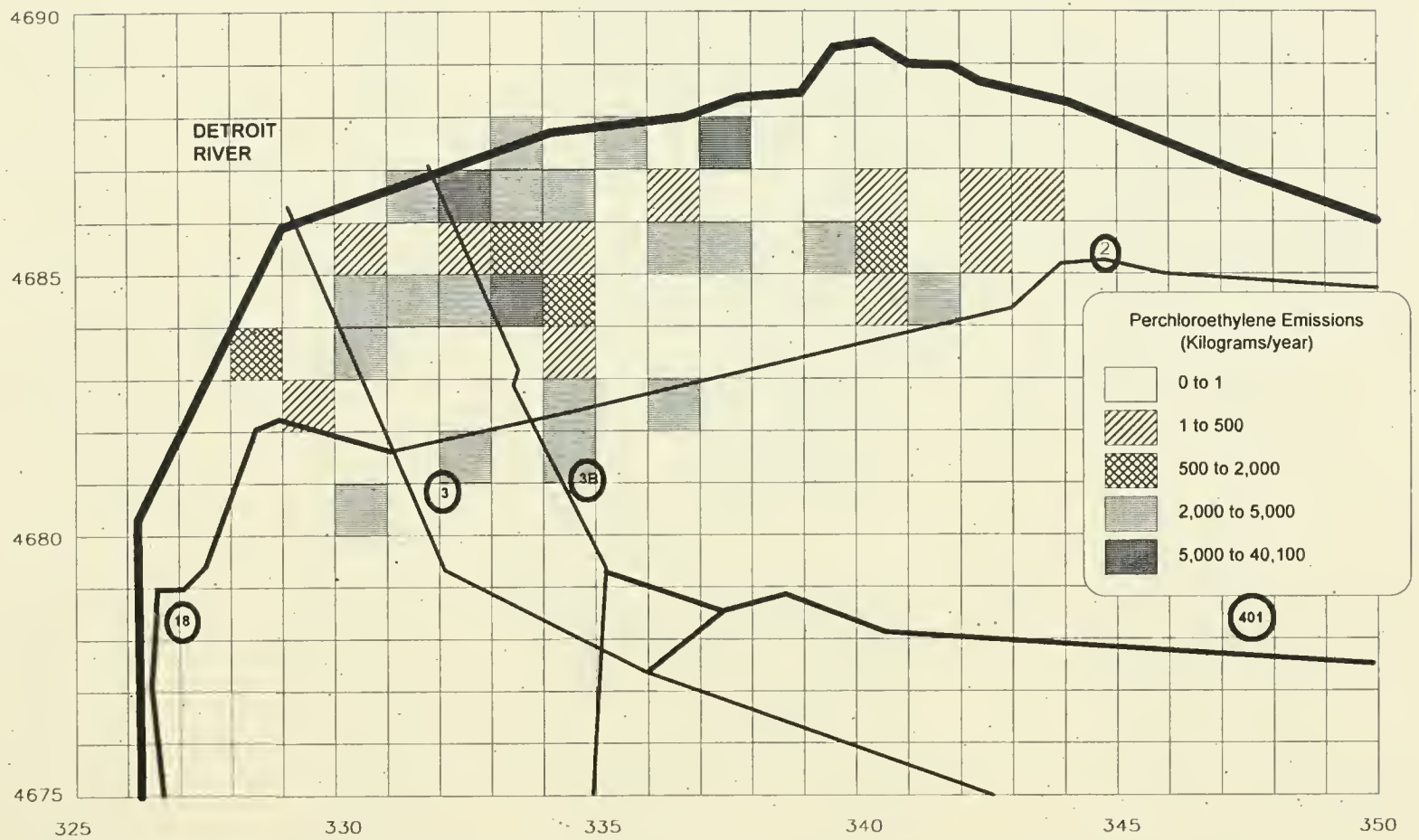
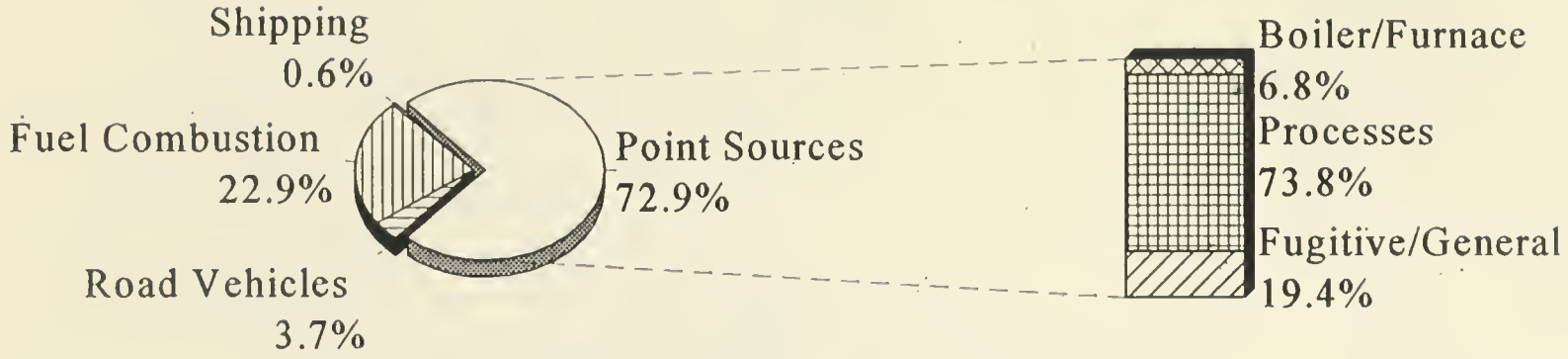


Fig. 16 Spatial Pattern of Annual Perchloroethylene Emissions

Fig. 17 Sources of Emissions

Chromium



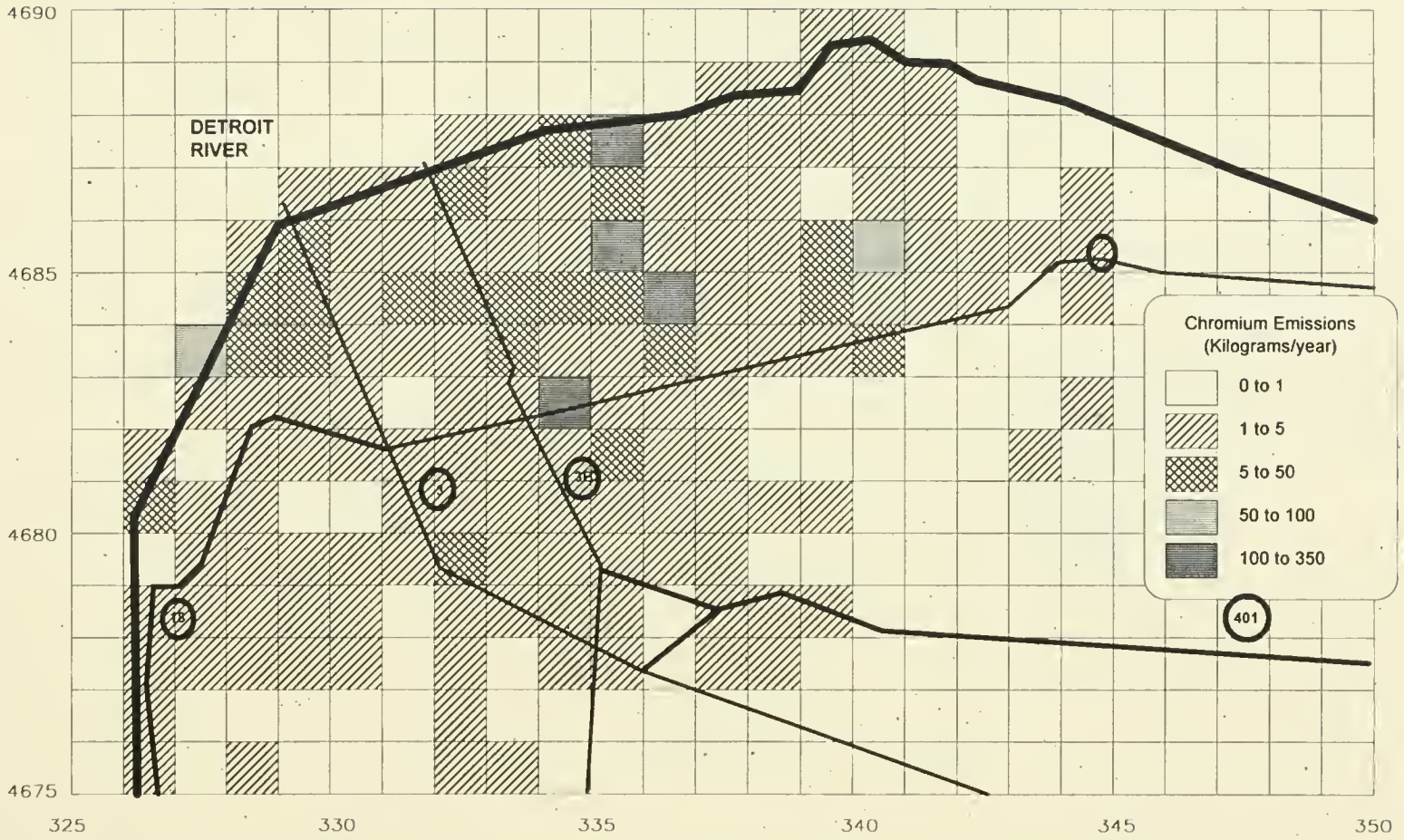
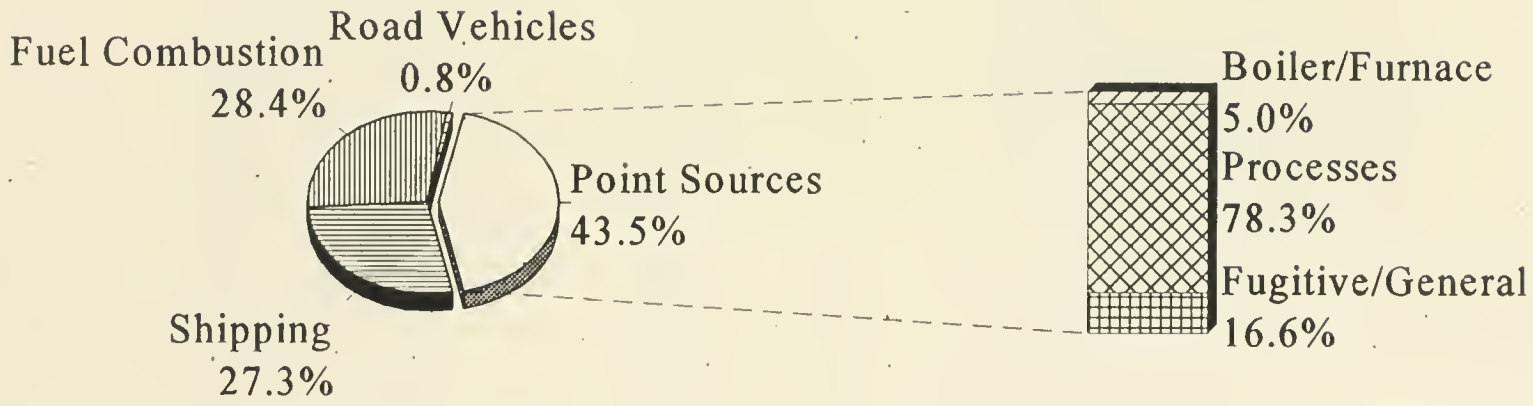


Fig. 18 Spatial Pattern of Annual Chromium Emissions

Fig. 19 Sources of Emissions

Nickel



fraction of cadmium in road dust particulate has been estimated to be 0.003% by weight for the PM; this fraction has been applied to estimate cadmium in the road dust.

Polycyclic Aromatic Hydrocarbons

The predominant area sources for the PAHs are stationary fuel combustion and transportation. Other ambient sources include meat cooking and cigarette smoking. The spatial distribution of PAHs emissions is presented in Figure 21. The emissions closely correspond with high population and traffic density. In order to be consistent for the comparison with the US sources, benzo (a) pyrene (BaP) , an important species of PAHs, was compiled. The emissions of BaP in Windsor were estimated to be about 56 kg in 1990.

Polychlorinated Biphenyls

About 87% of the total PCBs emissions (Figure 22a) in Windsor is from sewage treatment plants, and the others are due to the bituminous coal combustion of the industrial fuel sector (data prorated from the ORTECH study - ORTECH 1992).

Dioxins

The majority of dioxins in Windsor are emitted from the combustion of fuelwood and the vaporization of industrial effluent in the sewage treatment plants. Less than 1% of the total dioxins were estimated to be emitted from the medical incinerators. The contribution of dioxins emissions is shown in Figure 22b. The emissions are widespread throughout the area, due to the residential use of wood as fuel.

Furans

The primary source of furans is residential wood combustion. Since statistics on wood stoves and fireplaces were not available for the Windsor area, ORTECH

Fig. 20 Sources of Emissions
Cadmium

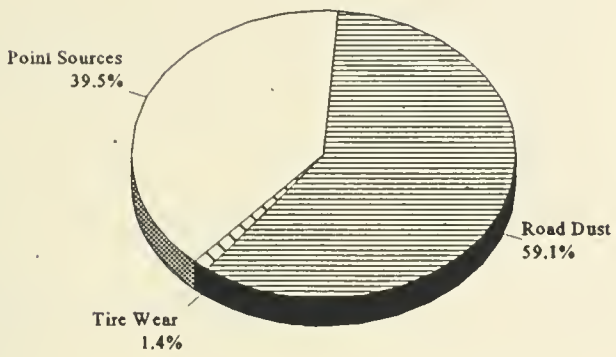


Fig. 21 Sources of Emissions

PAH

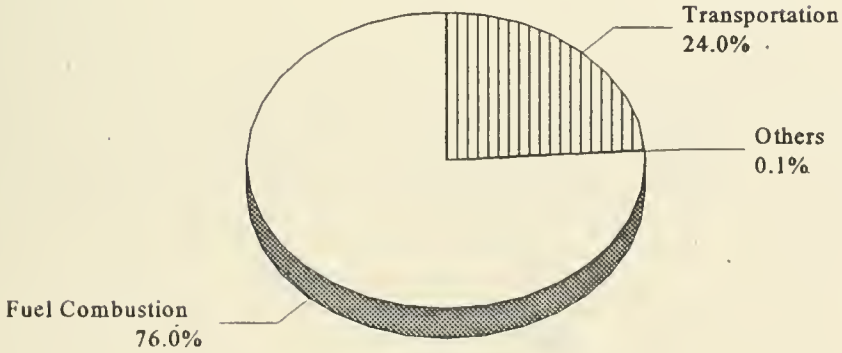


Fig. 22a Sources of Emissions
PCB

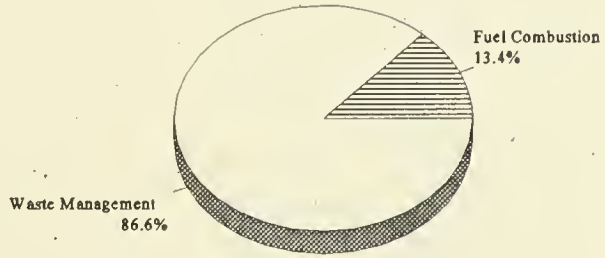


Fig. 22b Sources of Emissions
PCDD

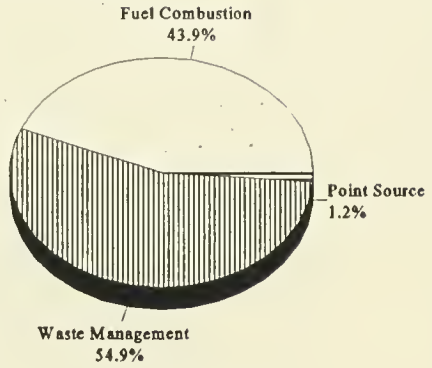
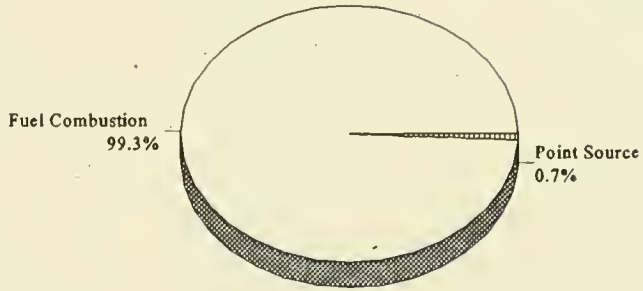


Fig. 22c Sources of Emissions
PCDF



data (ORTECH 1992), in conjunction with population and housing statistics, were used to estimate the emissions from the residential wood combustion sector. The total furans emissions in Windsor were estimated to be about 138 grams per year and the respective contribution sources are depicted in Figure 22C.

Arsenic is emitted from road dust, iron foundry and automotive casting processes. .

Beryllium

Trace amounts of **beryllium** are released from the machining of specialty metal.

Lead is released from area combustion sources in both the stationary and mobile sources. The main industrial sources are the iron foundry and automotive casting processes.

Manganese is released from point sources mainly in the iron foundry and automotive casting processes, and in much smaller amounts from combustion. The major area source is road dust. The road dust source is reflected in the spatial distribution of emission sources throughout much of the study area. The highest emission areas are those related to high traffic densities and point sources. In Canada, Methycyclopentadienyl Manganese Tricarbony (MMT) - an octane enhancer in gasoline, is a major source of vehicles' tail-pipe emissions of manganese.

Methylene Chloride

The majority of the methylene chloride emissions in Windsor are resulted from its consumer usage as solvent, paint stripper and degreasers. The Windsor industrial sector reported a very minimal usage of methylene chloride as compared to the consumer product source sector.

As in the case for chloroform, the predicted values based on the mathematical model are much less than the observed concentrations. Again, the unreported point sources and missing area emission sources may be some of the causes of discrepancies.

Mercury is released from the wind erosion of industrial waste storage, biomedical incinerators and from motor vehicle exhausts in very small amounts.

Acrylonitrile industrial emissions are from injection and dielectric moulding processes.

1,2-Dichlorobenzene is emitted from carburettor and choke cleaner use.

1,4-Dichlorobenzene is emitted from moth control products.

Ethylene dibromide is present in some industrial paints and released on application.

Vinyl chloride is emitted from the leachate from landfill sites due to decomposition and breakdown of polyvinyl chloride products.

4. EMISSION INVENTORY OF US TRANSBOUNDARY AREA

4.1 INVENTORY APPROACH

The US transboundary area, including Detroit, Michigan, has an approximate population of 4 million people, and a mix of industrial and other urban sources. The spatial distribution of US sources is presented in Figure 23.

The emission inventory for the above US region is based on the Engineering Science (ES) emission inventory databases. The sources in the inventory are mainly based on the 1985 National Acid Precipitation Assessment Program (NAPAP) data. For some sectors, information on the emission sources was not sufficient. These data gaps are discussed in Section 5.2.

4.1.1 US TARGET POLLUTANTS

The pollutants selected were generally those known to be observed in the transboundary region, known to cause carcinogenic risk and/or other substantial health risk. Target pollutants selected for the US transboundary inventories are listed below.

Target pollutant list for the US transboundary inventory

Chlorinated solvents

Methylene chloride, perchloroethylene and trichloroethylene

"Common" VOC

Benzene, 1,3 butadiene, carbon tetrachloride, chloroform, formaldehyde and

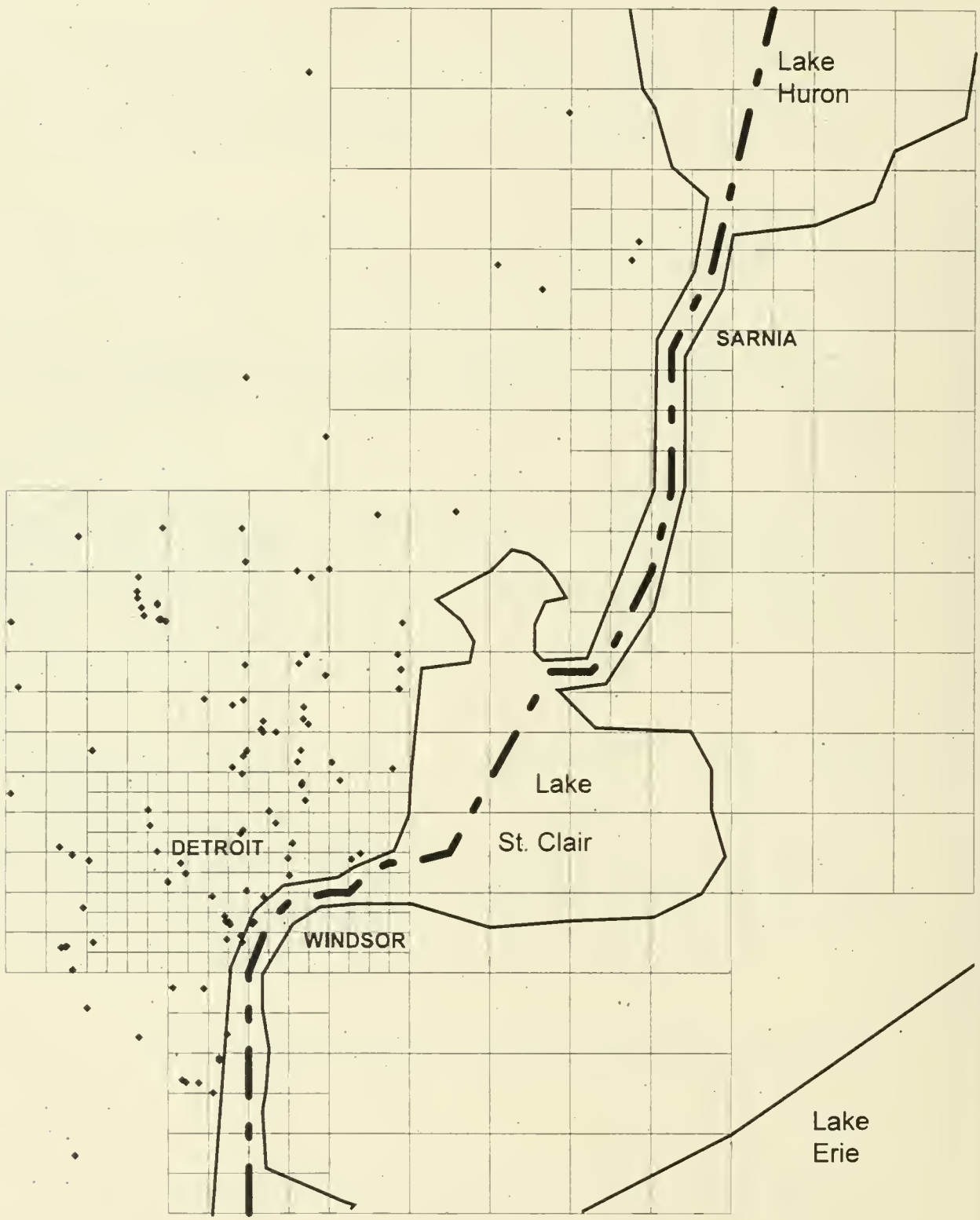


Fig. 23 Spatial Distribution of US Point Sources in the Transboundary Area

gasoline vapours

Metals

Arsenic, beryllium, cadmium, chromium, lead, mercury, nickel and selenium

Organic/Chemical Production and Reactions

Acrylonitrile, allyl chloride, dibutyl phthalate, epichlorohydrin, ethylene dibromide, ethylene dichloride, styrene, vinyl chloride, dioctyl phthalate, ethyl acrylate, hexachlorobenzene, hexachlorobutadiene, hexachloroethane, melamine, methyl chloride, octochlorostyrene, vinylidene chloride and polycylic organic matters (POM)

Pesticides

Chlordane, diazinon, guthion, heptachlor, parathion, aldrin and heptachlor epoxide

Polycyclic Aromatic Hydrocarbons (PAHs) and other products of Incomplete Combustion

B(a)P, PCDF, PCDD, chrysene, fluoranthene, methyl chrysenes, phenanthrene, coke oven emissions, dibenzen(a,h)anthracene, methyl benzanthracenes and PAHs

Specialty and Miscellaneous Substances

Asbestos, ethylene oxide, polychlorinated biphenyls and hydrogen sulphide

The difference in pollutants selected between the Windsor and the US transboundary inventories is attributed to the selection criteria based on the local

health risk concerns. In this respect, the two lists remain separate in this report.

4.1.2 US INVENTORY METHODOLOGIES

US Point Sources

The 1985 NAPAP data for the affected areas was supplemented by information obtained from the US National Emission Standards for Hazardous Air Pollutants (NESHAP) database and the Toxic Release Inventory (TRI). The NAPAP emission data included only VOC and PM emissions. Target pollutant emissions can be estimated by applying speciation profiles to the VOC and PM emissions, or by utilizing specific air toxics emission factors. The point sources considered include the iron and steel mills, motor vehicles manufacturing, petroleum refining, chemicals manufacturing and electric utilities.

US Area Sources

The NAPAP data only provided VOC and PM emissions from area sources for each grid cell of 20 km square in size. These VOC and PM emissions were speciated to the target pollutants, and the target pollutant emissions were allocated to the smaller study cells. The study cells range from 10 km square (one-fourth of a NAPAP cell), down to 5 km square and 2.5 km square. As many Source Classification Codes (SCCs) of area sources were described by the same profile, some SCCs were combined and the SCC list was reduced.

Mobile source emissions by grid cell were estimated by multiplying grid cell-specific VMT (Vehicle Miles Travelled) by grid cell-specific emission factors. Based on the VMT data, and vehicle fleet characteristics, MOBILE4 model was run to obtain VOC emission factors.

The area sources considered include the mobile sources, residential and commercial/institutional fuel combustion, rubber and plastic manufacturing, degreasing operations and dry cleaning.

4.1.3 US INVENTORY UPDATE/REVISION

US Point Sources

The original US transboundary database was enhanced by Engineering Science (ES) as shown below:

The plant emissions were resolved to individual stacks;

The information on stack parameters and geographic coordinates were completed and corrected;

Special sources (such as chrome platers) were added to the database.

Further update/revision was performed by MOEE on the ES database because the data sources of ES databases are primarily the 1985 NAPAP emission inventory, supplemented by data from 1987 Toxic Release Inventory (TRI) database, and 1989 State of Michigan and NESHAP databases. The update/revision included:

Two major industrial sectors in the ES database, namely the iron and steel sector and the electric utilities sector, were updated based on the Michigan inventory for State Implementation Plan (SIP) Submission of emission year 1991 (91 Michigan inventory), the most current available data from Michigan Department of Natural Resources (Michigan DNR). The iron and steel sector was chosen due to significant emission differences in the 91 Michigan inventory when compared with the ES database. As the 91 Michigan inventory provided VOC and PM emissions, these emissions were speciated to target pollutants using the US EPA methodology. Emission estimates from the 91 Michigan inventory were at the segment level and as such, these emissions were aggregated to point level, and were then apportioned into the various stacks according to the distribution of flowrate. In addition, the data was supplemented with the 1990 TRI database.

Some facilities in the other sectors of the ES database were excluded/revised because they were shut down/partially closed, up to the end of 1991. This action was based on the available information from

Michigan DNR and the Wayne County Air Pollution Division.

Since US VOC speciation profiles consider non-reactive VOC (e.g., methane) as components, MOEE adjusted the ES database for non-reactive VOC in the VOC speciation profiles where nonmethane VOC emission factors were used.

US Area Sources

Similar to point sources, the area sources have been adjusted for the non-reactive components in the US VOC speciation profiles for speciation of VOC emissions to target pollutants.

Emission data on total chromium is not available in the ES area source database, yet, this information is required for the Windsor study. The major area source categories which emit chromium include the fuel combustion, incineration and the mobile sources. The total chromium emissions were estimated by multiplying the lead emissions for each source by the ratio of the total chromium to lead in the speciation profile for each respective source category.

4.2 US TARGET POLLUTANT EMISSIONS

The industrial mix of the US transboundary area is very different from that of the Windsor City. Heavy industries such as the steel mills, the petroleum refineries and the electric utilities are located throughout Wayne County and its surrounding counties. The automobile manufacturing activities are prevalent on both sides of the Detroit River. The target pollutant emissions from the point and area sources in the US transboundary area by major sectors are summarised in Tables 12 to 14. The MOE-revised US transboundary inventory results were based on the update/revision of the ES databases. There are 202 facilities in the point source inventory. Emission totals of individual pollutants were reported as zero when emissions of individual point sources were less than one pound per year. A commentary on the target pollutant emissions by sectors is provided below.

TABLE 12

US TRANSBOUNDARY AREA
SUMMARY OF EMISSIONS FROM US POINT SOURCES BY INDUSTRIAL SECTORS
(x1,000 KG/YEAR)

POLLUTANT	STEEL MILLS	PETROLEUM REFINING	VEHICLE MANUFACTURE	UTILITIES	OTHER POINT SOURCES	TOTAL POINT SOURCES
ACRYLONITRILE	17	–	–	–	2	19
ARSENIC	2	1	2	2	3	10
BENZENE	116	38	31	1	94	280
BENZO (A) PYRENE	0.0041	0.0445	–	–	–	0.0486
BERYLLIUM	–	–	0.03	–	1	1.03
1,3-BUTADIENE	–	–	21	–	21	42
CADMIUM	1.3	0.1	0.6	0.2	0.6	2.8
CARBON TETRACHLORIDE	–	1.4	1.3	–	0.4	3.1
CHLOROFORM	–	1.8	1.7	–	0.5	4.0
TOTAL CHROMIUM	23	0.01	0.76	2.05	2.49	28.31
DIOXINS	–	–	–	–	0.0027	0.0027
FORMALDEHYDE	9	739	10	9	13	780
FURANS	–	–	–	–	0.0027	0.0027
LEAD	28.83	0.03	5.09	1.33	4.46	39.74
MERCURY	0.001	0.003	0.08	–	1.211	1.295
METHYLENE CHLORIDE	3	–	38	–	52	93
NICKEL	5	2	5	2	4	18
PCBs	–	0.040	0.04	–	0.12	0.20
PERCHLOROETHYLENE	6	2	44	–	3	55
TRICHLOROETHYLENE	18	1	307	–	39	365
VINYL CHLORIDE	0.0004	–	–	–	–	0.0004

NOTE:

Data Source: MOEE-Revised Transboundary Emission Inventory.
– denoted either insignificant value or no emission sources detected.

TABLE 13

US TRANSBOUNDARY AREA
SUMMARY OF EMISSIONS FROM US AREA SOURCES BY MAJOR SOURCE CATEGORIES
(x1,000 KG/YEAR)

POLLUTANT	FUEL COMBUSTION	MOBILE SOURCES	DRY CLEANING	OTHER AREA SOURCES	TOTAL AREA SOURCES
ARSENIC	1	--	--	1	2
BENZENE	1475	3224	--	1666	6365
BENZO (A) PYRENE	2.58	4.08	--	0.02	6.69
BERYLLIUM	--	--	--	--	--
1,3-BUTADIENE	--	1831	--	1245	3076
CADMIUM	2	--	--	0.6	2.6
CARBON TETRACHLORIDE	--	--	--	16	16
CHLOROFORM	--	--	--	2	2
TOTAL CHROMIUM	3	1	--	0.04	4.04
FORMALDEHYDE	77	1022	--	467	1566
ETHYLENE DIBROMIDE	--	43	--	--	43
LEAD	132	81	--	1	214
METHYLENE CHLORIDE	--	--	--	190	190
MERCURY	0.51	--	--	--	0.51
NICKEL	16.50	0.01	--	0.40	16.91
PERCHLOROETHYLENE	--	--	2411	343	2754
TRICHLOROETHYLENE	--	--	--	975	975
VINYL CHLORIDE	--	--	--	85	85

NOTE:

-- denoted either insignificant value or no emission sources detected

Data Source : MOEE-Revised Transboundary Emission Inventory.

TABLE 14

US TRANSBOUNDARY AREA
SUMMARY OF EMISSIONS FROM US POINT AND AREA SOURCES BY TARGET POLLUTANTS
(x1,000 KG/YEAR)

POLLUTANT	TOTAL POINT	TOTAL AREA	TOTAL EMISSIONS
ACRYLONITRILE	19	–	19
ARSENIC	10	2	12
BENZENE	280	6365	6645
BENZO (A) PYRENE	0.05	6.69	6.74
BERYLLIUM	1.03	–	1.03
1,3-BUTADIENE	42	3076	3118
CADMIUM	2.8	2.6	5.4
CARBON TETRACHLORIDE	3	16	19
CHLOROFORM	4	2	6
TOTAL CHROMIUM	28	4	32
DIOXINS	0.0027	–	0.0027
ETHYLENE DIBROMIDE	–	43	43
FORMALDEHYDE	780	1566	2346
FURANS	0.0027	–	0.0027
LEAD	40	214	254
METHYLENE CHLORIDE	93	190	283
MERCURY	1.30	0.51	1.81
NICKEL	18	17	35
PCBs	0.20	–	0.20
PERCHLOROETHYLENE	55	2754	2809
TRICHLOROETHYLENE	365	975	1340
VINYL CHLORIDE	–	85	85

NOTE:
– denoted either insignificant value or no emission sources detected
Data Source: MOEE-Revised Transboundary Emission Inventory.

US Point Sources

The **steel mills** sector (Table 12) comprises all facilities directly involved with steel and coke manufacturing, including steel mills, iron foundries and steel finishing facilities (also includes fuel/waste combustion sources). These steel mills and related facilities emit various pollutants, including 116,000 kg/year of benzene and 9,000 kg/year of formaldehyde. Benzene and formaldehyde are mostly emitted from iron foundries and fuel combustion. The steel mills sector contributes 1.7% and 0.1% to their respective emission total of point and area sources for benzene and B(a)P (Table 14). Their relatively low percent contributions are because all the coke oven batteries that are present in the ES database are not in the 91 Michigan inventory as they were shut down before 1992 (coke ovens were shut down at that time). Heavy metals emissions vary from 1 kg/year for mercury to 28,800 kg/year for lead. These emissions are mostly from the agglomerate charging of blast furnaces and other operations in steel mills, and from fuel combustion due to trace metals in fuel. Steel mills are the predominant sources of acrylonitrile, primarily emitted from steel works and steel finishing operations. Methylene chloride and perchloroethylene are also released from steel mills, mainly due to their usage in degreasing operations.

The **motor vehicle manufacturing** sector includes all facilities directly involved with motor vehicle assembly operations, especially manufacturing of vehicle bodies and parts, plus vehicle assembly (also includes fuel/waste combustion sources). Motor vehicle manufacturers' emissions include 307,000 kg/year of trichloroethylene and 38,000 kg/year of methylene chloride. Trichloroethylene, methylene chloride and perchloroethylene are primarily released during degreasing purposes. Heavy metals and "Common" VOC emissions are also emitted from the sector, due mostly to the automotive casting and iron foundry operations. Benzene is also emitted from fuel combustion and volatile organic compounds evaporation. Chloroform and carbon tetrachloride emissions are mainly from fuel combustion and surface coatings.

Heavy metals emissions in the **electric utilities** vary from 0.2 kg/year of mercury to 2,000 kg/year of arsenic, mostly as the result of fuel combustion. Formaldehyde and benzene are also primarily emitted from fuel combustion.

The main pollutants emitted from the **petroleum refining** are formaldehyde and benzene; their emissions are 739,000 kg/year and 38,000 kg/year, respectively. The fluidized catalytic operation is a significant emitter of formaldehyde. Heavy metals are also emitted, primarily from fuel combustion.

Other point sources include chemical manufacturing, incineration facility and documented solvent use at industrial facilities including degreasing. The chemical manufacturers are significant emitters of acrylonitrile. Vinyl chloride is also emitted from the miscellaneous industrial manufacturing, especially in chemicals production. Heavy metals emissions are primarily from fuel combustion. Emissions of dioxins and furans are solely from the municipal waste incinerator in Detroit since all point sources emitting less than the cut-off level (i.e., 1 lb/year pollutant) were not included in the ES point source database. 50% of the total PCBs emissions is due to one source in TRI database, and the others are due to documented waste oil use. Benzene is also emitted from volatile organic compounds evaporation.

US Area Sources

Mobile sources (Table 13) include gasoline fuelled motor vehicles, diesel fuelled motor vehicles, aircrafts, railroad locomotives and refuelling operations at gasoline stations. Benzene, 1,3 butadiene and formaldehyde emissions from mobile sources are 3224,000 kg/year, 1831,000 kg/year and 1022,000 kg/year, respectively. The mobile sources sector contributes 48.5% and 60.5% to their respective emission total of point and area sources, for benzene and B(a)P (Table 14). These emissions are mostly from the tail-pipe emissions and evaporative losses of the motor vehicles. Since refuelling operations at gasoline stations are included, gasoline vapours are also emitted. The benzene component in gasoline vapours was considered separately, and reported as a part of total benzene emissions. Heavy metals are also emitted from mobile sources, including 10 kg/year of nickel emissions.

Area sources of **fuel combustion** include residential and commercial/institutional fuel combustion, minor utilities and waste incineration sources. The main pollutants from this sector include benzene, 1,3 butadiene and lead. B(a)P is emitted primarily from wood burning.

Perchloroethylene emissions are predominantly from the **dry cleaning** operations, contributing 85.8% of the emission total for point and area sources (Table 14).

Other area sources include residential, agricultural and small industrial sources. Sources of benzene, formaldehyde and 1,3 butadiene include the miscellaneous volatile organic compounds evaporation and storage tanks. Heavy metals are emitted mostly from fuel combustion. Ethylene dibromide is mostly emitted from the application of architectural coatings and industrial paints.

5. DISCUSSION OF EMISSION INVENTORY RESULTS

5.1 DISCUSSION - WINDSOR vs. DETROIT

The Detroit inventory has been assumed to approximate that of Wayne County. The inventory results by target pollutants for both point and area sources in the Windsor and Detroit inventories (Table 15) are discussed below.

"Common" VOC

Of the combined Windsor and Detroit airshed, Windsor contributes 4%, 2% and 4% of the **benzene, 1,3 butadiene and formaldehyde** emissions, respectively (Table 15). These emission differences could be due to the much larger mobile sources emissions in Detroit, attributed primarily to its population being about 10 times larger than that of Windsor. Mobile sources are the predominant emitters of these pollutants in both Detroit and Windsor. For benzene, the emission difference could also be due to larger emissions in Detroit from area sources of fuel combustion and gasoline marketing, and point sources of iron foundry/automotive casting and miscellaneous volatile organic compounds evaporation than Windsor. For 1,3 butadiene, there are significant sources in Detroit from area sources of rubber and plastics manufacturing, and point sources of internal engines fuel combustion, plastics fabrication and volatile organic compounds evaporation. For formaldehyde, the presence of petroleum refineries in Detroit and not in Windsor increases the emission difference. In addition, Detroit has larger emissions from industrial sources of fuel combustion, iron foundry/automotive casting and volatile compounds evaporation than that of Windsor.

Of the combined Windsor and Detroit airshed, Windsor contributes 37% and 18% of the **chloroform and carbon tetrachloride** emissions, respectively. These emission differences are relatively less than that of other target compounds. This is because of the presence of one predominant source in Windsor, originating from chloroform and carbon tetrachloride use in the production of refrigeration gases. In Detroit, these emissions are mostly from point sources of fuel combustion and surface coatings, and an area source of miscellaneous industrial

TABLE 15

WINDSOR EMISSIONS COMPARED WITH DETROIT INVENTORY
(x 1,000 kg/year)

POLLUTANT	POINT SOURCES		AREA SOURCES	
	DETROIT	WINDSOR	DETROIT	WINDSOR
1,3-BUTADIENE	6	0.006	1,709	34
ACRYLONITRILE	19	2	--	--
ARSENIC	7	0.2	0.7	1.2
BENZENE	143	60	3,468	80
BENZO (A) PYRENE	0.048	--	3.3	0.056
CADMIUM	2.6	0.2	1.4	0.3
CARBON TETRACHLORIDE	3	2.6	9.4	0.06
CHLOROFORM	4	3	1.4	0.1
CHROMIUM	25	1	1	0.4
DIOXINS	0.003	--	--	--
ETHYLENE DIBROMIDE	--	0.1	20	--
FORMALDEHYDE	762	6	970	69
FURANS	0.003	--	--	--
LEAD	37	4	92	8
MERCURY	1.11	0.1	0.3	0.01
METHYLENE CHLORIDE	25	0.4	119	52
NICKEL	14	1	6	2
PCB	0.2	--	--	--
PERCHLOROETHYLENE	35	41	1,338	75
TRICHLOROETHYLENE	150	--	612	10
VINYL CHLORIDE	--	--	50	0.04

Note: Figures represented by '--' are insignificant.
Detroit inventory is assumed to approximate that of Wayne County

manufacturing.

Chlorinated Solvents

Of the combined Windsor and Detroit airshed, Windsor contributes 8%, 27% and 1% of the **perchloroethylene, methylene chloride and trichloroethylene** emissions, respectively. For perchloroethylene, this difference is expected due to the larger emissions from dry cleaning in Detroit, attributable to its larger population than Windsor. However, the point source emissions in Windsor are higher than Detroit because a dry cleaning depot in Windsor has been grouped under point sources. For methylene chloride, the emission difference is due to the larger emissions from Detroit's larger industrial base in degreasing operations and surface coating. The difference has been reduced by the methylene chloride use in the consumer products category in Windsor. The emission difference for trichloroethylene can be explained by the larger emissions from the industrial degreasing operations in Detroit, attributable to its larger industrial base than Windsor.

Heavy Metals

Windsor's emissions vary from 5% to 15% for individual heavy metals in the airshed. The point source emission difference is expected because Detroit has larger emissions from iron foundry and automotive casting operations than Windsor. In addition, Detroit has emissions from the other processes in steel production. The area source emission difference is due to Detroit's larger emissions from fuel combustion and mobile sources. Arsenic emissions from area sources in Windsor are greater than Detroit because road dust emissions are included in the Windsor inventory, but not in the Detroit emission inventory. The larger point source chromium emissions in Detroit than Windsor are due to the chrome plating, agglomerate charging of blast furnaces at steel facilities and fuel combustion.

Specialty and Miscellaneous substances

Windsor's **acrylonitrile, ethylene dibromide and vinyl chloride** emissions contribute 10%, 1% and 0.09%, respectively, to the airshed. For acrylonitrile, the emissions from the chemical manufacturers, and the steel finishing at steel mills in Detroit are larger than those from the injection and dielectric moulding processes in Windsor. For ethylene dibromide, Detroit's emissions from the applications of architectural coatings and industrial paints are larger than those from application of paints in Windsor. For vinyl chloride, Detroit has much larger emissions from the miscellaneous industrial manufacturing, especially in chemicals production, and area sources than Windsor.

B(a)P, Dioxins and Furans

Windsor's emissions contribute 2%, 3%, 5% and 0.1% of **B(a)P, dioxins, furans and PCBs**, respectively, to the airshed. For B(a)P, the emissions from area source fuel combustion, especially that of wood, and mobile sources, are larger in Detroit than those in Windsor. Ambient B(a)P emissions from meat cooking and cigarette smoking were estimated in the Windsor inventory. However, the US inventory did not include these source sectors in their data. Dioxins and furans emissions in Detroit arising from the municipal waste incinerator were estimated to be larger than those from biomedical incineration in hospitals, sewage treatment and residential wood combustion in Windsor. PCBs emissions in Detroit from the one source in the TRI database, and the others from documented waste oil use are much larger than those released from sewage treatment plants in Windsor.

5.2 DATA GAPS AND UNCERTAINTIES

Emission data for the Windsor and Detroit areas were improved during the study period by using feedback from an air quality model and observation results comparison. Earlier model-observation comparisons provided quality control to direct decisions in defining the parts of the emission inventory which required the most attention. Where possible, the reason for any model-observation discrepancy was identified. The detailed model results will be discussed in a separate report entitled "Windsor Air Quality Study: Mathematical

Modelling/Source Apportionment" (Bloxam and Sahota, 1994).

Windsor Inventory

The sources of the uncertainties in the urban target pollutant emission inventories are discussed below:

(1) Incomplete and inaccurate company data: Uncertainties could arise due to the fact that the emission questionnaire cannot capture all the variations and fluctuations in the operating conditions of the manufacturing processes. Also, some companies may not provide sufficient information to qualify the accuracy of their emissions. In addition, the inaccurate information provided may be due to non-technical personnel completing the survey questionnaires;

(2) Base quantities derived from local sources do not agree with provincial quantities prorated to the Windsor area;

(3) The speciation profiles assigned to volatile organic compounds and particulate compounds are mainly from United States information. The speciation profiles assigned to many area source emissions and, to a lesser degree, to point source emissions were derived from generic profiles developed by US EPA. Since these generic profiles were based on US conditions which could be different from Canadian conditions, a degree of uncertainty could exist in Windsor emission estimates. A typical example is the application of a Pasadena freeway road dust profile to the Windsor area. The types of chemicals in the road dust may not significantly differ in the two locations; however, the concentration for individual chemicals may vary substantially due to the different industry mix and Windsor's proximity to the Lake St. Clair;

(4) Particle size distributions : Heavy metals contained in larger particulate would settle out in the vicinity of the source and the particle size distributions would vary from source to source. These facts could account for the heavy metal model-observation discrepancies;

(5) As discussed in Section 3.2, the model results for both chloroform and methylene chloride are much lower than the observed values. According to R. Bloxam's report (Bloxam and Sahota, 1994), the most probable cause for the differences is the emission sources. However, it should be noted that chloroform emissions from Windsor are comparable to those of Detroit, SE Chicago and E. St. Louis (Table 16) compiled by other agencies. Also, the methylene chloride emissions from Windsor are of the same magnitude compared to that of Detroit (Table 15). The discrepancies should therefore merit further studies;

(6) The estimation of emissions from landfills in Windsor is based on the following information: the presence of VOC in the leachate analysis (Dillon, 1988), and the VOC emissions based on the US EPA landfill model and the Surface Impounding Modelling System (SIMS). However, the accuracy of the emission estimation is limited by the following:

(a) There is very limited analytical data for either flux measurement or the ambient concentration of VOC from the landfills;

(b) The is no available information on the density of the waste solid, volumetric water content in the waste matrix (therefore the values are assumed based on that of soil), organic carbon partition coefficient and waste bulk density.

Detroit Inventory

Most of the uncertainties in the Detroit inventories could be due to the following points:

(1) The sources in the inventories are mainly based on 1985 NAPAP data, despite MOEE's efforts in updating/revising the inventories for the Windsor Air Quality Study;

(2) Some methods of emission estimation may not be current;

(3) Insufficient information was available on some emission sources.

Insufficient information exists regarding whether point sources emitting less than 1 lb pollutant per year have been lumped into area sources; for example, dioxins and furans emissions from incineration. The absence of dioxins and furans emissions in the complete US transboundary inventory, except the contribution from the municipal incinerator, could suggest that these incineration emissions may not have been included in the US transboundary inventory.

The US transboundary inventory does not seem to include the following sources:

(1) Road dust;
(2) VOC from the consumer products category, landfills, sewage treatment and tire wear;
(3) Heavy metals and dioxins from the sludge incineration;
(4) PAH and VOC from meat cooking and cigarette smoking;
(5) Dioxins and furans from woodstoves.

Without knowing the base quantities, site-specific information and location of these sources, it is difficult to estimate their emissions accurately (this also applies to the missing point sources in the US transboundary inventory).

5.3 COMPARISON WITH OTHER URBAN EMISSION INVENTORIES

A **brief** comparison of Windsor emissions with two other urban target pollutant emission inventories is presented in Table 16. The emission data for SE Chicago and E. St. Louis were obtained from "Target Pollutant Volatile Organic Compounds in Urban Air in Illinois" (Sweet and Vermette, 1992).

The Southeast Chicago area is about 64-km^2. The iron and steel and related industries dominate the area's manufacturing base and inventoried emissions. Associated with the iron/steel industries are open storage locations for coal, slag, scrap steel, limestone, and other raw materials. Other significant facilities include an auto assembly plant, a municipal sewage treatment plant, a hazardous waste incinerator and numerous landfills.

The East St. Louis study area is bounded by the Mississippi River on the west and includes the municipalities of East St. Louis, Sauget and Cahokia. The city

TABLE 16

COMPARISON WITH OTHER URBAN TOXIC EMISSION INVENTORIES BY POLLUTANTS

(x1,000 KG/YEAR)

COMPOUND	SOUTHEAST CHICAGO	EAST ST. LOUIS	WINDSOR
BENZENE	3,328	2,753	139
TOLUENE	2,693	546	N.A.
ETHYLBENZENE	60	127	N.A.
O-XYLENE/STYRENE	479	1,650	2 (STYRENE ONLY)
CHLOROBENZENE	654	800	N.A.
CHLOROFORM	12	9	3
1,1,1-TRICHLOROETHANE	94	18	N.A.
TRICHLOROETHYLENE	197	18	10
1,4-DICHLOROBENZENE	81	586	12
CARBON TETRACHLORIDE	20	56	3
PERCHLOROETHYLENE	173	28	116

N.A. denoted information not available.

of St. Louis is located to the west across the Mississippi River. The dominant manufacturing activities in the study area are copper and zinc smelting and organic chemical production.

Windsor's emissions are much less than those of SE Chicago and E. St. Louis for all target pollutants except perchloroethylene where Windsor has a dry cleaning depot which is a major source of perchloroethylene. It should also be noted that the basis of the emissions estimation methodologies for the SE Chicago and E St. Louis Studies may not be consistent with that of the Windsor Study.

6. CONCLUSIONS

Target pollutant emissions from Windsor are far less than those of the industrialized major cities of Detroit, SE Chicago and E. St. Louis. In Windsor, even though there is a large industrial sector, 67% of target pollutant emissions are from area sources and point sources contribute only 33%.

Windsor's emissions of target pollutants range from 82 gm/year for dioxins to 140,000 kg/year for benzene. In Windsor, the mobile sources are the major sources of "Common" VOC. The main sources for the heavy metals emissions include fuel combustion, mobile sources and iron foundry/automotive casting operations. Degreasing operations, dry cleaning and consumer product usage are the large emitters of chlorinated solvents.

When compared with Detroit, Windsor's point and area emissions are much smaller. This is due to the larger mobile sources, population and industrial base in Detroit. Windsor's contributions to the combined emissions of Detroit and Windsor were as low as 0.09% for vinyl chloride and as high as 37% for chloroform.

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